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AMERICAN SOCIETY
FOR
TESTING MATERIALS.

AFFILIATED WITH THE
INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

PROCEEDINGS
OF THE
SEVENTH ANNUAL MEETING

Held at Atlantic City, New Jersey,
June 16, 17, 18, 1904.

VOLUME IV.

EDITED BY THE SECRETARY, UNDER THE DIRECTION OF
THE COMMITTEE ON PUBLICATIONS.

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SUMMARY OF THE PROCEEDINGS OF THE SEVENTH ANNUAL MEETING.

ATLANTIC CITY, N. J., JUNE 16, 17, 18, 1904.

THE SEVENTH ANNUAL MEETING OF THE AMERICAN SOCIETY FOR TESTING MATERIALS was held at the Hotel Traymore, Atlantic City, N. J., on June 16, 17, 18, 1904. The total attendance at the meeting, including guests, was about 175.

The following members were present or represented at the meeting: W. A. Aiken; Ajax Metal Company, represented by G. H. Clamer; American Bridge Company, represented by C. C. Schneider; American Foundrymen's Association, represented by Richard Moldenke; S. W. Baldwin; James Berrall; A. Bonzano; W. A. Bostwick; C. W. Boynton; John G. Brown; H. I. Budd; F. O. Bunnell; Cambria Steel Company, represented by George E. Thackray; H. H. Campbell; William Campbell; Carnegie Steel Company, represented by John McLeod; R. A. Carter; Central Iron and Steel Company, represented by George R. Bentley; F. P. Cheesman; James Christie; Charles S. Churchill; Charles H. Clifton; J. A. Colby; P. H. Conradson; A. S. Cushman; Nathan H. Davis; Detroit Graphite Manufacturing Company, represented by F. W. Davis, Jr.; H. E. Diller; Joseph Dixon Crucible Company, represented by Malcolm McNaughton; A. W. Dow; W. C. DuComb, Jr.; Charles B. Dudley; W. O. Dunbar; W. R. Dunn; *Engineering Record*, represented by John M. Goodell; B. F. Fackenthal, Jr.; A. Falkenau; Henry Fay; A. P. Ford; Charles N. Forrest; G. M. Goodspeed; Charles S. Gowen; R. S. Greenman; J. E. Greiner; E. M. Hagar; N. A. Hallett; W. H. Harding; George B. Hartley; Henry J. Hartley; W. K. Hatt; George P. Hemstreet; Olaf Hoff; George H. Hull; A. P. Hume; Richard L. Humphrey; Joseph W. Hunter; Charles L. Huston; Illinois Steel Company, represented by P. E. Carhart; *Iron Age*, represented by Fred. W. Schultz; Joel Jenkins; Robert Job; A. L. Johnson; A. N. Johnson; W. M. Johnson; William

Jordan, Jr.; E. F. Kenney; William Kent; J. A. Kinkead; Paul Kreuzpointner; H. A. La Chicotte; G. Lanza; E. S. Larned; W. W. Lemen; R. W. Lesley; F. H. Lewis; G. Lindenthal; John B. Lober; Henry M. Loomis; Lukens Iron and Steel Company, represented by Charles L. Huston; T. D. Lynch; Charles F. McKenna; E. McLean; John McLeod; Charles Major; Edgar Marburg; Charles A. Matcham; E. R. Maurer; R. K. Meade; William Metcalf; R. P. Miller; Charles M. Mills; L. S. Moisseff; Richard Moldenke; H. F. Moore; A. W. Munsell; Tinius Olsen; L. W. Page; Patterson-Sargent Company, represented by W. A. Polk; The Pennsylvania Steel Company, represented by H. H. Campbell; W. A. Polk; H. H. Quimby; *Railroad Gazette*, represented by R. C. Davison; J. C. Ramage; C. S. Reeve; Clifford Richardson; J. Robinson; C. W. Roepper; Joseph Royal; A. H. Sabin; W. M. Saunders; Albert Sauveur; H. J. Seaman; C. W. Sherman; The Sherwin-Williams Company, represented by E. C. Holton; Jesse J. Shuman; C. E. Skinner; H. E. Smith; Henry S. Spackman Engineering Company, represented by E. W. Lazell; Standard Steel Works, represented by A. A. Stevenson; A. A. Stevenson; C. R. Stewart; P. M. Stewart; Emil Swensson; H. Taggart; A. N. Talbot; W. P. Taylor; G. W. Thompson; Sanford E. Thompson; F. E. Turneaure; Hermann Von Schrenk; S. S. Voorhees; Samuel T. Wagner; J. F. Walker; George C. Warner; George S. Webster; William R. Webster; Thomas D. West; M. H. Wickhorst; H. V. Wille; R. D. Wood and Company, represented by Walter Wood; Walter Wood; Ira H. Woolson; J. R. Worcester. Total number, 146 (including representations); total number in personal attendance, 139.

FIRST SESSION.—THURSDAY, JUNE 16, 3 P.M.

Business Meeting.

President Charles B. Dudley in the chair.

The minutes of the Sixth Annual Meeting were approved as printed.

The annual report of the Executive Committee and the report of the Auditing Committee were read and adopted.

The following amendment of the By-Laws, proposed by the Executive Committee, was passed to letter-ballot by unanimous vote:

That the first sentence of Section 2, Article IV, viz: "The annual dues of each member shall be $3.00" be amended by striking out $3.00 and substituting $5.00.

The Chair appointed Mr. Wm. Jordan, Mr. W. C. DuComb, Jr., and Mr. W. P. Taylor as tellers to canvass the ballot for officers.

The report of Committee E, on Preservative Coatings for Iron and Steel, was presented with introductory remarks by the Chairman, Mr. S. S. Voorhees.

Mr. Robert Job read a paper on "Results of an Investigation Concerning Causes of Durability of Paints for Structural Work."

A paper on "The Protection of Structural Steel," by Mr. C. L. Norton, and a paper on "Preservative Coatings for Iron and Steel," by Mr. Cyril De Wyrall, were, in the absence of the authors, read by title.

The report of Committee E and Mr. Job's paper were discussed jointly.

The tellers reported that 105 legal ballots for officers had been cast, and in accordance with their report the Chair declared the election of the following officers: Charles B. Dudley, President; R. W. Lesley, Vice-President; Edgar Marburg, Secretary-Treasurer, and James Christie, member of the Executive Committee.

The meeting then adjourned till 8 P.M.

SECOND SESSION.—THURSDAY, JUNE 16, 8 P.M.

President Charles B. Dudley in the chair.

The Chairman invited the Vice-President, Mr. R. W. Lesley, to the chair and read the Annual Address by the President on "The Influence of Specifications on Commercial Products."

Vice-President Lesley then yielded the chair to President Dudley, and Mr. William Metcalf read a paper on "Alloy Steels," which elicited considerable discussion.

This was followed by an illustrated address by Mr. R. W. Lesley on "Some Statistics of the Cement Industry in America."

The meeting then adjourned till the following morning.

THIRD SESSION.—FRIDAY, JUNE 17, 10 A.M.

Section on Cast Iron.

President Charles B. Dudley in the chair.

The report of Committee B on Standard Specifications for Cast Iron and Finished Castings was submitted in printed form by Mr. Walter Wood, Chairman.

This report embodied the proposed Standard Specifications for:

(*a*) Foundry Pig Iron.
(*b*) Pipe and Special Castings.
(*c*) Locomotive Cylinders.
(*d*) Car Wheels.
(*e*) Malleable Castings.
(*f*) Gray-Iron Castings.

Mr. Richard Moldenke gave a summary of the discussion of the above specifications at a meeting of the American Institute of Mining Engineers in March, 1904.

The specifications were then taken up and discussed separately with the following results:

Specifications for Foundry Pig Iron.—Referred back to committee with instructions to weigh the objections advanced, and to report to the Executive Committee; the Executive Committee to be authorized to submit the specifications to letter-ballot.

Specifications for Pipe and Special Castings.—These specifications were approved and referred to letter-ballot.

Specifications for Locomotive Cylinders.—The same action was taken on these specifications as on the Specifications for Foundry Pig Iron.

Specifications for Car Wheels.—These specifications were referred back to the committee for further study and instructions to report their conclusions at the next Annual Meeting.

Specifications for Malleable Castings.—It was the expressed sense of the meeting that the tensile strength limit should be changed from 42,000 to 40,000 lbs. per square inch. Otherwise, the same action was taken on these specifications as on the specifications for Foundry Pig Iron.

Specifications for Gray-Iron Castings.—Referred back to the committee for further study, with instructions to report their conclusions at the next Annual Meeting.

A paper on "Cast Iron: Strength, Composition, Specifications," by Mr. Wm. J. Keep, was read by title.

The meeting then adjourned till 3 P.M.

Section on Cement.

Vice-President R. W. Lesley in the chair.

The report of Committee C on proposed Standard Specifications for Cement was submitted in printed form.

Mr. R. L. Humphrey moved that the specifications be referred to letter-ballot of the Society.

Mr. Chas. F. McKenna proposed that the motion be amended by first referring the report back to the committee for further consideration and amendment.

After considerable discussion the amendment was lost and the original motion prevailed.

Then followed the reading and discussion of the following papers:

"Practical Cement Control." Charles F. McKenna.

"Some possible By-Products in the Portland Cement Industry." Clifford Richardson.

"The Boiling Test for Portland Cement." Frederick H. Lewis.

"Some Attempts to Limit the Personal Equation in Cement Testing." W. A. Aiken.

"Tests of Reinforced Concrete Beams." A. N. Talbot, F. E. Turneaure and Edgar Marburg.

"The Mechanical Defects of Sieves used in Determining the Fineness of Cement." E. W. Lazell.

The meeting then adjourned till 3 P.M.

FOURTH SESSION.—FRIDAY, JUNE 17, 3 P.M.

On Specifications.

President Charles B. Dudley in the chair.

The report of Committee A on Standard Specifications for Iron and Steel was read by the Secretary.

After some discussion this was followed by the reading of the "Report on the Specifications for Iron and Steel Structures, American Railway Engineering and Maintenance of Way Association, as Amended and Adopted in March, 1904," by Mr. J. P. Snow, Chairman.

In the absence of the author, Mr. H. V. Wille, the following paper was read by the Secretary: "Comparison of the Specifications for Axles and Forgings, Proposed by Committees of the American Railway Master Mechanics' Association and the American Society of Mechanical Engineers, with the Standard Specifications Adopted by the American Society for Testing Materials."

Then followed the reading of a "Report on the Specifications for Steel Rails, American Railway Engineering and Maintenance of Way Association, as Amended and Adopted in March, 1904," by Mr. Wm. R. Webster, Chairman.

After a general discussion on the desirability of considering amendments to the Standard Specifications for Iron and Steel, a motion by Mr. H. H. Campbell, that no change be made in the existing specifications and that they be printed in their present form, was withdrawn by the mover and the following motion substituted:

"That Committee A be instructed to consider the revision of the Standard Specifications for Iron and Steel with a view of bringing them into harmony, if possible, with those proposed or adopted by other committees and societies; that the report of Committee A on this subject, embodying its reasons for such recommendations as it may offer, shall be printed a sufficient length of time in advance of the next annual meeting to give ample opportunity for written discussion."

This motion was carried without a dissenting vote.

Mr. Max H. Wickhorst read a paper on "Specifications for Air-Brake Hose," which was followed by a discussion.

The meeting then adjourned till 8 P.M.

FIFTH SESSION.—FRIDAY, JUNE 17, 8 P.M.

President Charles B. Dudley in the chair.

The session was opened with an address by Mr. Gaetano Lanza, giving "A Brief Review of the Status of Testing in the United States."

The following papers were then read and discussed:

"Structure of Alloys." William Campbell.

"The Effects of Preservative Treatment on the Strength of Timber." F. A. Kummer.

Mr. Herman Von Schrenk made some informal remarks descriptive of the projected government tests on the preservative treatment of timber.

Mr. Gaetano Lanza offered the following resolutions, which were adopted:

Resolutions relating to the Investigation of Timber now under Operation in the Bureau of Forestry.

WHEREAS, The American Society for Testing Materials recognizes the need of tests to determine the structural value of the various species of commercial timbers of the United States, particularly those species suitable for second-growth supplies, and the Pacific coast timber; and the need of investigations of the methods of seasoning and preserving timbers; and

WHEREAS, It further recognizes the application of the results of this work in the design of safe and economical structures; in the best utilization of existing supplies of timber; and in making possible the conservative administration of forest tracts in the general interests of forestry;

Be it resolved, That this Society hereby records its appreciation of the timber tests now under operation in the Bureau of Forestry, United States Department of Agriculture, and urges the Honorable Secretary of Agriculture to request Congress to make such appropriations as may be necessary to carry on the investigations in the most effective and satisfactory manner.

The Secretary of the Society is hereby directed to send copies of these resolutions to the Honorable Secretary of Agriculture and to the Forester, Bureau of Forestry, United States Department of Agriculture.

Mr. Samuel Tobias Wagner read a paper on "The Early History of 60,000-pound Structural Steel."

This was followed by a paper by Mr. George H. Hull on "Pig Iron Feasts and Famines: Their Causes and How to Regulate Them."

On motion of Mr. Charles F. McKenna, it was resolved that the Executive Committee be instructed to consider the appointment of a committee on Standard Specifications and Standard Tests for Sewer Pipe.

The meeting then adjourned till the following morning.

SIXTH SESSION.—SATURDAY, JUNE 18, 10 A.M.

President Charles B. Dudley in the chair.

The report of Committee G on the Magnetic Testing of Iron and Steel was, in the absence of the Chairman, Mr. J. Walter Esterline, read by title.

The following papers were then read and discussed:

"The Commercial Testing of Sheet Steel for Electrical Purposes." C. E. Skinner.

"Permeability of Cast Steel." H. E. Diller.

"Proposed Tests for Controlling the Heat Treatment of Structural Steel." J. P. Snow.

"Tests for Detecting Brittle Steel." William R. Webster.

The meeting then adjourned till 3 P.M.

SEVENTH SESSION.—SATURDAY, JUNE 18, 3 P.M.

President Charles B. Dudley in the chair.

The report of Committee H on Standard Tests for Road Materials was presented by Mr. Logan Waller Page, Chairman.

The following papers were then read and discussed:

"Tensile Impact Tests of Steel." W. K. Hatt.

"The Desirability of a Uniform Commercial Speed for Testing." Paul Kreuzpointner.

At the suggestion of Mr. Paul Kreuzpointner, it was moved and carried that the Executive Committee be requested to consider

the desirability of appointing a committee to study and report on the question of a Uniform Speed for Commercial Testing.

The following papers were then read and discussed:

"Nomenclature of Iron and Steel." Albert Sauveur.

"Staybolt Iron and Machine for Making Vibratory Tests." H. V. Wille.

"A New Chuck for Holding Short Test-Pieces." T. D. Lynch.

A paper by Mr. P. H. Dudley on "Bending Moments in Rails" was read by title..

On motion of Mr. H. V. Wille, the Executive Committee was requested to consider the question of appointing a committee on Standard Specifications for Staybolts.

In pursuance of a motion on the part of Mr. W. K. Hatt the appointment of a committee on Specifications for the Grading of Structural Timber was referred to the Executive Committee.

Like action was taken on a motion of Mr. S. S. Vorhees for the appointment of a committee on Fire-Proofing Materials.

On motion of the Secretary, the meeting passed a unanimous vote of thanks to the Management of the Steel Pier for its courtesy in placing the pier at the disposal of the Society during the meeting.

The President thereupon declared the meeting adjourned *sine die*.

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PROCEEDINGS.

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THE INFLUENCE OF SPECIFICATIONS ON COMMERCIAL PRODUCTS.

ANNUAL ADDRESS BY THE PRESIDENT, CHARLES B. DUDLEY.

In the Annual Address, a year ago, an attempt was made to describe somewhat in detail how a specification for a commerialc product should be made. In view of the importance which specifications have thus far assumed in the work of our Society, it has occurred to us that we might perhaps not unwisely spend a few minutes together over another phase of specifications, namely, the influence which a carefully worked out and rigidly enforced specification has on the successful manufacture of commercial products.

It may perhaps be remembered that in our résumé last year of the parties involved in a specification, two were regarded as of prime importance, namely, the producer and the consumer; that both were recognized as having the right to a voice in the formation of the specification, and that in reality a properly drawn, carefully balanced specification covering any commercial product was a protection and an advantage to both the producer and the consumer. In the present paper we shall perhaps not go amiss if we consider a little more closely the side of the consumer, indeed we might perhaps have wisely chosen for our theme, "The Influence of the Consumer as expressed in Specifications on Commercial Products."

We are frank to say that it is our firm belief that the influence of the consumer on commercial products is far greater than is

commonly supposed. We are so accustomed to regard the great mass of commercial products as so completely in the hands of the producer, as something that the consumer is quite at liberty to take up or let alone as suits him, and as something in whose preparation he, the consumer, has had no voice, that the idea that the consumer does actually have an influence on, or exert some force in giving shape and form, or in deciding on the qualities which the article shall possess, does not seem evident at first sight. And yet we do not hesitate to reaffirm that the influence of the consumer appears in every successful commercial product, however great or however small, and that the consumer's power over the product, although perchance not appearing in formal and carefully prepared specifications, is nevertheless many times fully as great, or even greater, than that of the producer.

Let us see if this can be made evident by an illustration. The commercial product in question is so simple an article as a pair of shoes. The producer or manufacturer has decided seemingly almost everything about them. He has determined the style, the shape and the size, the materials in the uppers, the vamps and the soles, whether it should be button or lace, patent leather, French calf or cowhide, pegged or sewed, black or tan, and so on in infinite detail. And in each of these items he has not consulted the consumer, has had no specifications to work to, and apparently the consumer's voice in the matter has been nil. He can purchase the shoes or leave them, as suits him best. The manufacturer has gone ahead and filled his warehouses, and perchance in his mind has figured up the profits on his year's work. But in all this, has, as a matter of fact, the consumer no voice? I trow yes, as many a manufacturer has found to his sorrow and loss, who has too greatly ignored the power of the consumer in matters of this kind. If the shoemaker has used cowhide when the consumer wants French calf, his shoes are unsalable. If he has made a No. 6 size when the consumer's foot happens to be No. 9, there is a misfit and no business doing. If he has his whole product broad toes when pointed toes are the style and hence demanded by the consumer, his commercial product can hardly be said to be a successful one and he will undoubtedly have to dispose of it as best he can, oftimes at a loss.

But it may be urged, it is true, in staple articles of almost

universal use, the silent influence of the consumer on the product is granted. He would be a shortsighted producer who would attempt to ignore the demands expressed or understood, nay, even the foibles of the consumer, or, what amounts to the same thing would not study his market. But there are cases, such as the making of a new product for which a demand has yet to be created, where the influence of the producer on the product covers the whole field. The consumer does not yet understand the new product, does not yet know what kind of a material it should be, and hence can have no voice in its production. Take for an illustration the new high-speed tool steel. The manufacturer seemingly decides everything in regard to this new product, independent of the consumer. He first learns how to make the steel, decides what its composition should be, learns how to treat it, practically changes all our ideas as to what heat will do to a piece of steel, and develops a new art of hardening and tempering, and after his studies are finished, comes forth with his creation and teaches the consumer how to use it. Surely it may be urged, in such a case as this, the influence of the consumer on the product is not apparent. But those who so argue, we fear, can have had very little experience at the birth and death of new things, many of them good new things, which might have had perchance a long life of usefulness if their sponsors had not attempted to ignore the legitimate influence which the consumer has on even new commercial products, the fruit apparently of the brain energy of the producer alone.

The influence of the consumer on new commercial products is usually made manifest in the price he is willing to pay for it. If the new product is higher in price in proportion to results obtained than that which he is at present using, or if, even though economies are shown, he conceives the price is unreasonable, he will usually go on as he has been doing in the past, with the result that the new product fails to be successful. Makers of new things far too often make one or both of two serious mistakes. They either fail to sufficiently study the present condition of the field which their new product proposes to occupy, and as a consequence make the product cost so much to manufacture that it cannot successfully compete with what is already in the field, or, having studied the field carefully and thoroughly and having developed

a new product which is a decided step forward over present practice and which produces notable economies, they place a price on their product, such that the ultimate economy to the consumer is so small that there is no real reason why he should change. Not once, but scores of times, have we seen new commercial products fail from one of these two causes. The man who fails to study his field and makes his product cost too much should have our pity for his shortsightedness. The man who, having devised and worked out something new, which may be actually useful and valuable, and who claims for himself all the financial advantage of the step forward, will find, if our observation and experience are worth anything, that he is killing the goose that may lay golden eggs for him, and that the disappointment which will inevitably follow his action is no more than a just punishment for his attempt to ignore the right of the consumer to a share in the advantage which comes from the progress of knowledge. This is hardly the time or the place to discuss this point to a conclusion, but we cannot help feeling that the legitimate sphere of the consumer is far too often almost completely ignored by those who are developing and exploiting new products. The point which we are trying to make is that always and everywhere, in every successful commercial product, the producer and the consumer each has a legitimate sphere, and that any attempt on the part of either to ignore the other will result in disappointment and failure. As we have tried to urge on other occasions, it is only by working together, by each respecting and honoring the rights and privileges of the other, that successful results can be obtained.

There is another view of this case, which will perhaps bear a few moments' consideration. A sound commercial transaction is one from which both sides secure advantage. A producer has something to sell, from which he hopes to reap the reward of the successful business man. How shall he best accomplish this? Surely not, as is too often the case, by trying to give the buyer or consumer that which he may happen to have in stock, whether it is fit or not, and trying to persuade him that it will be found all right; but, on the other hand, by trying to understand what the consumer really needs, and devoting his energies to furnishing that thing and nothing else. Or again, a consumer has a want and goes to a producer for something to meet that want. Shall the

producer, for the sake of the immediate transaction, supply that which he knows will not give ultimate satisfaction? The temptation is certainly great, and the loop-holes and possible explanations of failure are so many that it is to be feared in too many cases the transaction is accomplished without due regard to its effect on subsequent business. But I stoutly maintain that such procedure is shortsighted business policy, and that far too soon those who habitually do not give satisfaction will find their customers slipping away from them. In business parlance, "they cannot hold their trade."

These business truisms would have no place in the theme which we are trying to discuss, except as they illustrate again the intimate relation between the interests of the producer and the consumer, and especially the influence which the consumer has on the successful commercial product.

Thus far we have considered the influence of the consumer, which is, so to speak, not expressed. It is a silent influence, an unwritten specification, one real and tangible in its effects, but which has never attained to the dignity of being expressed in words or print. But our real theme is the influence of carefully worked out, written or printed specifications, which are rigidly enforced, on commercial products. Perhaps we shall best bring out what we have in mind on this theme, by dipping into the history of some of the forty or more specifications which have been prepared at Altoona during the past twenty-five years.

The history of the Lard Oil Specifications is an instructive one. When they were first prepared, now over twenty years ago, two grades of lard oil were in common use by railroads, known as "Prime" or "Extra," and "No. 1 Lard Oil." The former, which was the best oil that could be made from the materials, was largely used as the principal constituent of what is commonly known as "Signal Oil," the oil which the conductors burn in their lanterns, and which at that time was used also in almost all signal lanterns everywhere. The function which this oil must perform is a very important one, since the safety of trains depends on the reliability of signals. The other grade, or "No. 1 Lard Oil," was and is principally used for lubrication. Both these oils, when pure and of good quality, gave excellent results in the places where they were used. The prices of both were high, the better grade often

reaching a dollar a gallon, and the inferior grade from 70 to 85 cents per gallon. The better oil is light amber in color, while the poorer is inclined to red, and, as the quality diminishes, becomes more of a brown. The better oil is made from lard that is taken from freshly killed hogs, and is sweet and good enough to be used in cooking. The poorer oil is made from second or third grade lard, known in market as "No. 1 Grease" or "No. 2 Grease," and usually comes from hogs that have died in transit. All the animal fats, as is well known, are glycerides; that is, when they are in the animal, at least in good health, they are some characteristic fat acid, chemically combined with glycerine. But as soon as the animal dies from any cause, decomposition apparently sets in, one of the results of which is the separation of the fat acid from the glycerine. This separation is apparently also facilitated by the operation of rendering. Whatever the cause, the better grade of lard oil usually contains from one to four or five per cent of free fat acid, and the poorer grade may contain from ten to twenty-five per cent of the same. The influence of this free fat acid on the service of these two oils is deleterious. Careful experiments, many times repeated, show conclusively that a signal oil made from a prime lard oil containing the higher percentages of free fat acid given above will go out from crusting the wick much sooner, requires more frequent renewal of the wick and greater care, and is in every sense a less reliable signal oil than one made from a lard oil containing less free fat acid; while in the case of the poorer grade of lard oil, it is found that the more free acid it contains, the poorer it is as a lubricant, and the more rapidly the journals and bearings disappear by wear. All this detail is necessary in order that what follows may be understood.

About a year or perhaps two or three years before the Lard Oil Specification was made, a new product came forward, which has continued to the present day, which had added greatly to the wealth of the South, and which appears in more places in our modern civilization than many of us are aware of. The oil referred to is made from the seeds of the cotton plant, and is commonly known as Cottonseed Oil. This oil is a beautiful bright, clean, almost odorless material, containing very small amounts of free fat acid, but in its properties is unfortunately on the border ground between the drying and the non-drying oils, having some

of the characteristics of both. It is not enough of a drying oil to be used successfully in paints, and on the other hand is too much of a drying oil to be used successfully either for burning or lubrication. It crusts the wicks, and the light goes out in four or five hours; and it gums so badly as to be almost useless for lubrication. The price at the time of which we are writing was fifty cents a gallon. What now could be more natural than that this oil in some way should find its way into the lard oils which have been described above? It diminished the free fat acid of both grades, and especially improved the appearance and apparent salability of the poorer grade, to say nothing of the delicious rake-off of from twenty to fifty cents for every gallon of it used in the mixture. That it was being so used was suspected by consumers for some little time before the Lard Oil Specification was prepared, but it was only a suspicion; the chemistry of oils was at that time so poorly understood that no one could prove it. The use of the oils in service indicated it, but that was all. A couple of weeks' rather hard study in our laboratory developed a test which about a year later was independently developed by another observer and published, which made it possible to say with rather remarkable certainty whether a sample of lard oil was pure or not. It was not always possible to say what the admixture, if any, was; but if cotton-seed oil was present, the amount could be told to within one per cent. Also a method of determining free fat acid in oils was developed. Armed with these two tests, the oils of the market were questioned. At first, small samples were obtained and examined before orders were placed, it being required simply that shipments should be like sample. The first month's samples numbered thirteen, and only three were found to be pure and of the proper quality. The next month's samples were seventeen, of which seven were satisfactory. In the course of a few months, or as soon as the trade became convinced that only those who furnished samples which were free from admixture of other oils, and were satisfactory in other respects, would get orders, all the monthly samples would pass the necessary tests, except that occasionally a new party would be asked for samples, in which case it usually took two or three months to convince him that nothing but straight goods would pass muster. But now a new difficulty arose. The samples would be all right, but the shipments or deliveries

would be all wrong. Not a few contests were characteristic of those days, which contests were marked on the part of the producer by wordy assertions, by appeals to business reputation and standing, and by threats of litigation, and, on the part of those in charge of the purchase and use of the goods, by a quiet determination to defend to the death the interests committed to their care. Not yet in this particular industry had the producer learned that there were limits to his power over his own product, and that the consumer had rights which even he, the maker and owner, must not ignore. Fortunately, notwithstanding the bluster, the strife was confined largely to words; and after the affray, which lasted a year or more, was over, it was found that the conflict had resulted, so far as the producer was concerned, in some loss of business, in some financial loss due to paying return freight charges on rejected shipments and in traveling expenses to Altoona for the word combats above referred to, and also in a serious loss of business reputation. It is perhaps not too much to say that, as a matter of fact, within a year or a year and a half after this contest began, not a few of those who for years had furnished lard oil were stricken off the Purchasing Agents' lists, and to this day have not succeeded in reinstating themselves. On the part of the consumer, the results of the contest were gratifying. Improvement in the service immediately followed, and bills were paid with the knowledge that a full honest equivalent was furnished for the money spent. The information accumulated during these few months of contest was ultimately embodied in specifications, and for many years now, although safely hundreds, perhaps thousands of shipments have been tested, there has been scarcely a rejection for failure to meet requirements. Perhaps more important than all, a beginning had been made toward the establishment of a principle, viz.: the influence and rights of the consumer in any commercial product, if it hopes to be successful, can never be ignored or lightly set aside. The special teaching which we would draw from this episode, as applicable to our theme, "The Influence of Specifications on Commercial Products," would be that enforced specifications protect the honest dealer from unfair competition. The concomitant protection against purchasing an inferior product at the price of a better one, and against using inferior materials in most important service which they give the consumer, will not escape notice.

Perhaps some additional side light on our theme may be thrown by the history of another Altoona specification. It is now perhaps twenty-five years ago that a certain special car happened to fall under the eye of one of the officers responsible for the maintenance of equipment, who observed that the varnish on the outside seemed to have perished almost completely, and that the integrity of the painting underneath was in consequence seriously threatened. The car was sent to the paint shop for special examination. The shop reported that the car had been varnished at so recent a date that ordinary wear would not warrant its present condition, and that the loss of varnish was probably due to excess of zeal on the part of the car cleaners. The matter was referred to the foreman of the car cleaners, who reported that they had given the car a pretty good treatment, but that really they could not be held responsible for any better results with the soap that was furnished to them. In order not to be set aside and diverted from his efforts to secure efficiency by the customary attempt on the part of subordinates who are called to account, to transfer the blame to some one else, the officer above referred to asked for a sample of the very soap used, and a partly used cake was furnished and sent to the laboratory. Now ordinary cleaning soap, as is well known, is a chemical compound of the various acids characteristic of vegetable or animal fats, with either soda or potash or both. The combination is brought about by the aid of heat, the fats being mixed with the soda or potash in water solution, and the resulting product always containing more or less water as a necessary concomitant of the manufacture. Potash, being more expensive than soda, is less often used, also potash soaps are softer than soda soaps. But, as is well known, the physical condition of a soap as to hardness is an important element in its successful use. Moreover, the nature of the fats used has a most important influence on the hardness of the soap. The soft animal fats whose characteristic fat acid is undoubtedly largely oleic, when saponified gives a more or less soft mushy soap which is uneconomical to use, is less easy to handle both in manufacture and transportation, and is often unsalable in appearance. These objectionable characteristics are largely increased by the practice so common among soapmakers, of adding a percentage of rosin to the fat. Tallow which contains a considerable percentage of stearic acid, makes a much better

soap. But tallow is more expensive than the soft fats and rosin. Accordingly soapmakers have sought for devices that would harden soaps made from the soft fats and rosin, and it has been found that an excess of alkali, and especially a percentage of carbonate of soda added toward the last, and thoroughly mixed with the soap before it cools and hardens, produces the result desired.

Returning now to the partially used cake of soap. A careful analysis of this sample showed that it contained, in addition to the alkali necessary to combine with the fat, about three and a half per cent of free caustic soda, and over seven per cent of carbonate of soda. It will thus be seen that the water solution of this soap which the men were using to clean the cars with, was in reality a weak lye, containing quite an amount of sodium carbonate. But both lye and carbonate of soda in solution readily dissolve varnish, nay, even the combined alkali of a normal soap dissolves varnish to a certain extent, but very much more slowly than free caustic or carbonated alkali, even though the latter may be in very dilute solution. It is evident that the contention of the men in this case had a foundation of fact, and while it is recognized that the manipulation, that is, the method of using the soap solution, is a most important element in the problem, it is unquestioned that in the hands of the ordinary car cleaner, such a soap as has been described will result in a much more rapid destruction of the varnish than if a normal soap were used. This incident led to the formation of specifications for soap in which the amounts of free caustic and carbonated alkali were limited, and no similar case of very rapid varnish deterioration has since been noticed.

Now this case has not been cited to show that the producer had any desire to ignore or set aside any of the rights or even desires of the consumer, or to obtain for himself any undue ulterior advantage at the expense of the consumer. In reality the producer was furnishing more detergent power per pound of soap than is characteristic of the normal article, since both free caustic and carbonated alkali are much stronger in detergent power per pound than the combined alkali of soaps. There is apparently no reasonable ground for an attempt to hold the soapmaker responsible for the injury to the varnish, and we cannot help regarding this episode as illustrating "The Influence of Specifications on Commercial Products," in this, that they tell the pro-

ducer what the consumer wants. It is not to be supposed that the producer will know all the uses to which the consumer will apply his product, and without co-operation on the part of the latter, or as we have so many times urged, without the two working together, the producer may with perfect honesty make and furnish the wrong product.

Perhaps you will bear with me a few minutes longer. Our theme is so prolific that I fear I shall strain your patience. But I cannot deny myself one more illustration of "The Influence of Specifications on Commercial Products," this time from the field of steel metallurgy. No individual specification, but rather a group of specifications will be considered. For our purpose it will be sufficient to choose out from the innumerable uses of steel, three grades, soft, medium and hard. Let the boiler and fire-box steel specifications represent the first, the axle and crank-pin specifications represent the second, and spring steel specifications the third. Now it is well known that the grades of steel defined by these specifications differ from each other principally in the amount of carbon which they contain. The limiting amounts of the other constituents are of course not all alike, but the principal difference making the various steels applicable to their designed use is in the carbon, approximately 0.18 of a per cent for boiler and fire-box steel, 0.45 of a per cent for axles and crank pins, and 1 per cent for spring steel. When these specifications were first drawn, some of them provided only for physical tests, some for chemical tests only, and some for both. Whatever the method of testing the shipments, however, when the specifications were first made, they provided only lower limits; that is to say, in fire-box steel, a minimum tensile strength and a minimum elongation were specified. The manufacturer might furnish a product as much above these minimum limits as he chose. Exactly the same restrictions applied to the axle and crank-pin steel. In spring steel a minimum content of carbon was given with no upper limit. Two or three reasons led to this procedure. First, there was the desire to leave the maker the widest possible freedom in the manufacture of the material; second, there was at that time no known reason why there should be any upper limit; and third, it was actually thought that a minimum limit in strength and elongation being secured, or a minimum amount of carbon, the product would really be better

the more these minimum limits were exceeded. But as time progressed, and especially as the study of parts that had actually failed in service—that never-ending source of valuable information—became wider and wider, it began to appear that an upper limit likewise was a desideratum in specifications. The boiler plate sent when there was no upper limit occasionally gave difficulty in the shops in flanging, cracking at the bends, and an analysis and physical test of such plates demonstrated beyond question that the carbon and the tensile strength were too high for successful hand flanging at such temperatures as are usually employed in this operation. Axles and crank pins which under the slow-moving strain of a tensile test, or under the drop test as then carried out, would quite fill the requirements, would not infrequently fail in service, either by breaking in detail, or as the analysis would frequently show, due to an improper proportioning of the chemical constituents. Spring steel with a lower limit of carbon only would occasionally fail in service, owing apparently to over-hardening with the very high carbons, or would give difficulty in the shops when working it, owing to the wide range of carbon in a shipment. Moreover, as the knowledge of the influence of carbon, and especially of manganese, and silicon, on the physical properties of steel increased, and especially once again as the analysis of parts that had either broken or failed in some other way in service, or had given difficulty in the shops, began to increase and become an element in the making of specifications, it became evident that the chemistry of steel was destined to play a continually more and more important part in obtaining a metal that would give best results. Accordingly it was decided to revise existing specifications and introduce both an upper limit in tensile strength, and also as much chemistry, with both lower and upper limits, especially in the carbon, as the information at hand seemed to indicate was necessary to secure the proper material. But upper and lower limits of carbon involve the idea of a range. How much shall the upper limit be above the lower limit? Obviously, if the range was too narrow, the steelmaker would find it difficult, if not impossible, to make the metal. On the other hand, if the range was too wide, it would go far toward defeating the end to be accomplished by the introduction of upper and lower limits. In view of this dilemma it was with some misgivings that specifications embodying these

features were prepared and issued. The limits finally decided on were from 0.15 to 0.25 per cent of carbon, or a range of ten points for soft steels such as fire-box, from 0.35 per cent to 0.50 per cent or a range of fifteen points for medium steels, such as are used in axles and crank pins, and from 0.90 per cent to 1.10 per cent or a range of twenty points for hard steels such as are employed in making springs. It is gratifying to be able to state that the limits have not proved too narrow. With very few exceptions the steelmakers have cheerfully and successfully worked within these limits. Is it too much to say that twenty years ago this would have been thought impossible? How many steelmakers twenty or twenty-five years ago felt sure enough of their furnaces and their methods so that they would be willing to take orders and guarantee successful outputs on such limits as these? It of course is not claimed or even thought that this decided step forward in steel metallurgy is wholly due to specification, but is it too much to claim that the results now possible are in part at least due to the stimulus put upon the producer by the demands or desires of the consumer as embodied in specifications?

There is another phase of this stimulating influence of specifications on commercial products that will perhaps bear a word. In our experience, the first draft of a specification for any commercial product not heretofore bought on specifications is apt to contain not a few uncertainties. The consumer has been taking what the manufacturer gave him, without special study of its behavior in service, and the producer has been sending what the consumer would take, contenting himself in his study of his product usually to such problems as affected his successful output. Neither the producer nor the consumer rightly understand the material, the consumer because he has not yet carefully questioned the service as to what are its demands in the matter, and the producer because he knows his product principally at least only from the standpoint of a maker, and the consumer has not yet told him his side of the story. Accordingly a first draft specification, as already stated, is usually founded on more or less incomplete knowledge, and will be fortunate if it runs eight months or a year without revision. But when a material arrives at the dignity of being bought on specifications, and every shipment is examined, much more attention is paid to its behavior in the service, and indeed every characteristic

of it is studied. This study not infrequently leads to the idea that modifications in the product are not only desirable, but ofttimes essential if the usefulness and adaptability of the material in the place where it is being used are to be maintained. Moreover, the growth in size of almost everything connected with railroads is not only demanding continually new designs to meet the increased strains, but also, in view of the limitations of space, constant changes in the nature of the materials employed in construction are likewise essential, if unwieldy not to say impossible designs are to be avoided. A few illustrations will perhaps make these points clear.

The mass of the first steel used in fire-boxes contained from 0.10 per cent to 0.13 per cent of carbon. But a few years of service developed the fact that such soft lead-like steel was badly abraded by the coal, and failed to satisfactorily hold the thread on the stay bolts. Hence, in the specification at present in force, a harder metal, whose carbon has already been given, was asked for. This change introduced no serious difficulties in manufacture, and very large quantities of the harder product have been furnished, and more successfully used, for some years now.

The first steel passenger-car axles contained from 0.22 per cent to 0.26 per cent of carbon. But in the course of a year or two a number of these soft axles broke in detail, and a study of the case led to a demand for a stiffer steel for this purpose. Accordingly, when the present chemical specification for axles was prepared, the limits of the carbon were placed at from 0.35 per cent to 0.50 per cent, as has already been stated. These proposed limits led to no small amount of discussion. At that time few, if any, axles had ever been made containing over 0.30 per cent of carbon. It was feared that even though the proposed metal might be successfully made in the furnace, it could not be successfully forged. One steelmaker told us in plain language we were making a most serious mistake, and that we would rue it. Another opposed the proposed specification in every reasonable way possible, and only took an order under it with the utmost misgiving. It is gratifying to be able to state that this latter maker of axles has within two years stated that the present axle specification was in every sense a most satisfactory one, and hoped it would never be changed. So great was the uncertainty and doubt about the ability to success-

fully make axles in accordance with this specification that the first deliveries were actually billed at $3\frac{1}{2}$ cents a pound. Within four months the price dropped to $1\frac{3}{4}$ cents. Furthermore, a couple of years ago indications began to manifest themselves that even the present axle specification required modification in such a way as to require a stiffer metal still. Accordingly a number of the steel-works were visited and the matter talked over with the experts, as to whether they would be willing to try to make axles with from 0.50 per cent to 0.65 per cent of carbon. No one was found willing, but within six months word was sent by one of the works that they would gladly try it. Under the stimulus of the request, experiments had been made which promised a successful outcome, and although the question of stiffening the present axle has not yet been decided, there seems no good reason to fear that if higher carbon is decided on as the best solution of the problem, there will be any difficulty in obtaining it. Ten years ago we would have hardly dared to hope for it.

One more illustration of the stimulating effect of the consumer on commercial products, and I have finished. It was for a long time customary to use only crucible steel in making springs, either helical, elliptic or semi-elliptic, and in these springs the carbon employed was usually from 0.65 per cent to 0.75 per cent. The service of these springs was very unsatisfactory. The breakage was something appalling, such that at some of the important repair shops a car-load of broken helical springs would accumulate in a few months. At that time the springmakers decided on both the kind of steel to use and the design. They were given the space that could be allowed for the spring, and the load it must carry, and they did the rest. In fairness it should be stated that the conditions were severe, and that apparently neither producer nor consumer understood the situation. Very few tests had ever been made, and apparently the strains in the metal had never been calculated. The matter was taken up with some vigor by the consumer's experts and an attempt made to get an understanding of the situation. It developed that when some of the helical springs then in use were brought down solid, the strain in the outside row of fibers was over 110,000 pounds per square inch. What wonder that the springs broke. As a result of the study of the matter, a specification was prepared covering both the design and the quality

of steel to be used. In view of the small space available, and with the tendency toward increasing loads already mentioned, it was felt that every advantage must be taken, and accordingly a round bar was decided on as being best able to resist the strains, instead of the flat or oval, which had previously been used, the maximum fiber stress was placed at 80,000 pounds per square inch, instead of the indefinite 110,000 pounds or more which had been characteristic of previous practice, and also a 1 per cent carbon steel was specified instead of 0.70 per cent, as had previously been used. Still further, no mention was made of the process by which the steel should be made.

This proposed specification likewise met with some antagonism. It was urged, not without a good deal of show of reason, that crucible steel was the only fit material to use in making springs, and that so hard a steel as is given by 1 per cent of carbon would be unreliable and probably cause more difficulty than had heretofore been experienced. It should perhaps be added for information that at this time the possibility of making a high-carbon steel in the open-hearth furnace had not been fully demonstrated, and that this proposed spring specification, leaving out the process by which the steel should be made, was a direct stimulus in the development of this method. The crucible steel people were therefore naturally a little anxious. It is undoubtedly well known that at the present time by far the largest portion of the steel used in springs is made in the open-hearth furnace. Notwithstanding the antagonism, the specification as drawn was sent out, and although there were some difficulties at the start, and one springmaker at least refused to fill orders, it soon became evident that the specification was going to survive. The results in service were most gratifying. When 30,000 helical springs according to specifications had been put in service, a count was made of those which had broken, and only two were found. After three or four years, when there were perhaps two or three hundred thousand of these springs in service, a request was sent to one of the principal repair shops to send twenty broken springs to the laboratory, in order that the relation between phosphorus and broken springs might be studied. At the end of three months, only twelve had been secured, and these were used as the basis of the investigation. The effect of the specification on the producer was equally satisfactory.

Special and patented forms of bars absolutely disappeared, the open-hearth steelmakers soon learned how to make with perfect success a high-carbon steel, and from being antagonistic the spring-makers soon changed to the warmest friends of the specification, and recommended it everywhere to other railroads. It is perhaps not too much to say that 95 per cent of all the freight cars built in the United States within the last twenty years are fitted with helical springs closely patterned after or made in accordance with the specifications whose birth we have been trying to describe.

It would be easy to continue this discussion to almost any length, but I spare you. Nearly every one of our forty or more specifications at Altoona has a more or less interesting history, and some of them would illustrate points in our theme which we have not been able to bring out. But I fear this paper is already too long, and that I have wearied your patience. The conclusions from the episodes given and from the incidents recounted have perhaps been made sufficiently clear as we have gone along in our discourse. But I am sure you will bear with me while I give you one general conclusion which to our minds sums up the whole matter, viz:

The influence and voice of the consumer in the manufacture of commercial products have come to stay, and it is simply the part of wisdom for all concerned to recognize the situation. Also, since both the producer and consumer have each a direct interest in the product or thing made, the one in its production and sale, and the other in its use, there is no real reason why each should not study the product in most minute detail. If the producer knows better than the consumer, as he undoubtedly does, the effect of composition and details of manufacture on the thing made, so also does the consumer, if he studies as he should the behavior of materials in service, know better than the producer knows or can know, the relation between the composition, the physical properties, or even minute characteristics of the thing made and its successful use. It is only by the combination of information from each of these two sources that perfectly successful commercial products can be obtained. Finally, if these views are accepted as correct, is it not evident that all energy spent in antagonizing each other is so much lost effort, and that the true policy is to work harmoniously together in our attempt to convert the crude materials of Nature into a shape to be useful in the service of man?

REPORT OF COMMITTEE A ON STANDARD SPECIFICATIONS FOR IRON AND STEEL.

A meeting of Committee A was held jointly with Committee B some months ago to consider the proposed Standard Specifications for Cast Iron and Finished Castings. It was intended to discuss at that time also the various matters that had been referred to Committee A at the last annual meeting. In view of the small representation of Committee A on that occasion it was decided to reserve the discussion of these matters for a special meeting to be called specifically for that purpose.

Before issuing a call for this meeting, the Chairman addressed a circular letter to the members requesting an expression of individual opinion on the general question of the desirability of considering various modifications in the Standard Specifications proposed by committees of other societies, and in part adopted by these societies. The replies to this circular inquiry, though in the main favorable to the proposition, were largely non-committal. Certain members thought it undignified to introduce any modifications in the present specifications so soon after their adoption; others considered it undesirable to make any changes until the specifications had been subjected to a longer trial; while again others expressed their conviction that it was imperative to introduce certain modifications in order to bring the specifications into line with their conception of the best current practice.

Inasmuch as the modification of specifications adopted as standard by the Society as a whole involved an important question of general policy, and since the sentiment of the Committee on this point was evidently greatly divided, the Chairman thought it expedient to submit this question to the judgment of the Society at this meeting. If it be the sense of the meeting that the time has come to consider a revision of the specifications, especially with reference to such modifications as have been proposed or adopted by other representative bodies, a meeting of Committee A will be called at an early date to take action in accordance therewith.

In that connection it is interesting to call attention to the

movement that has been recently initiated in England, on similar lines and under conditions which are, in part, distinctly more favorable than those under which we are laboring; namely:

(1) In that the work is under the joint auspices of the five leading technical societies, viz:

The Institution of Civil Engineers,
The Institution of Mechanical Engineers,
The Institution of Naval Architects,
The Iron and Steel Institute,
The Institution of Electrical Engineers.

The personnel of the various committees is made up of representatives of these five societies as well as officers of the War Office and Admiralty Department. Representation on these Committees has been accorded also to numerous engineering, scientific and trade associations, to the International Association for Testing Materials as well as to the leading manufacturing and consuming interests.

(2) In that the British Government is lending financial support to the work in the form of a grant of £3,000, the Indian Government having appropriated an additional sum of £1,000. The Committees have further the direct financial support of the five above-named technical societies.

The scope of the field which this Committee on Engineering Standards proposes to cover may be judged from the following list of Committees and Sub-committees:

1. Sections used in Ship Building (11 members).
   (*a*) Sub-Committee on Tests for Iron and Steel Material used in the Construction of Ships and their Machinery (23 members).
2. Bridges and General Building Construction (12 members).
3. Railway Rolling-stock Underframes (13 members).
4. Locomotives (28 members).
   (*a*) Sub-Committee on Component Parts and Tires (14 members).
   (*b*) Sub-Committee on Steel Plates (7 members).
   (*c*) Sub-Committee on Tires, Axles and Springs (6 members).
   (*d*) Sub-Committee on Copper and its Alloys (6 members).

5. Rails (22 members).
   (*a*) Section on Railway Rails (11 members).
   (*b*) Section on Tramway Rails (4 members).
6. Electrical Plant (22 members).
   (*a*) Sub-Committee on Generators, Transformers and Motors (13 members).
   (*b*) Sub-Committee on Temperatures of Insulation Materials (5 members).
   (*c*) Sub-Committee on Cables and Conduits (11 members).
   (*d*) Sub-Committee on Telegraphs and Telephones (7 members).
7. Screw-Threads and Limit-Gauges (26 members).
   (*a*) Sub-Committee on Screw-Threads (26 members).
   (*b*) Sub-Committee on Limit-Gauges (17 members).
8. Pipe-Flanges (12 members).
9. Cement (17 members).

Three of the above-named committees have considered independently the question of "Standard Sections for Rolled Iron and Steel," have held joint meetings and have agreed upon standard sections which have been adopted and published.

It is perhaps not too much to expect that eventually on the completion of the reports of the English committees, the results of their work and our own may be harmonized, provided that the American Specifications have the endorsement in their present or modified form of the leading kindred societies, so that they may be recognized as truly representative American specifications.

Respectfully submitted,

WILLIAM R. WEBSTER,
Chairman.

EDGAR MARBURG,
Secretary.

DISCUSSION.

THE PRESIDENT.—Shall we revise the specifications after having had them out for the short space of a year or two, and bring them up to date, or shall we print them and issue them in permanent form without modification? The President

H. H. CAMPBELL.—I move that there be no change made in the specifications and that they be printed as they are. (Motion seconded.) Mr. Campbell

These specifications of ours are the results of conferences with a number of engineers and engineering societies and of at least ten years of discussion. Every point has been threshed and rethreshed over and over again, and no specification will suit every man in this room. This specification as it stands represents the engineers and manufacturers better than any other one specification.

W. R. WEBSTER.—While it is true as Mr. Campbell says, that these specifications have been submitted to other societies, yet, if I remember correctly, this was not done until they were in their present form. To-day we have the reports of two or three of the committees of other societies on our specifications and I think we should give careful consideration to the modifications, they recommend before reprinting the specifications in their present form. Mr. Webster

EDGAR MARBURG.—It has been frequently said that our specifications should not yet be revised because they have been in force only about three years. By some standards of measurement, three years is a short period; but if we consider what has been done along these lines in the meantime, it is a long period. We have invited other societies to discuss and criticize our specifications and this has been done both in open meeting and through committees whose reports are now available in printed form. These reports are in the main favorable to our specifications; but a number of changes on points of more or less importance have been recommended. The question is, can we afford to disregard these recommendations? It seems to me that the Society should continue Mr. Marburg

Mr. Marburg. to take a broad and liberal view of things; that we should welcome light from any source whatever that will enable us to see our way more clearly to correct conclusions. I do not refer to minor points of difference which can never be wholly avoided; but to the more important points in which the specifications reported to other societies differ from our own. To dismiss these in what might appear to be a perfunctory or arbitrary manner would merely serve to defeat whatever purpose might prompt such a course.

It seems to me that the proper attitude for the Society to assume in these matters is not to stand on its dignity and do nothing, but to give fair and full consideration to what has been formally proposed by other societies, by inviting their representatives to attend meetings called for that very purpose. Let our committees be instructed to give careful consideration to the leading points of difference with a view of reconciling the same if possible. Let these committees be requesetd to state in their reports their reasons for or against the modifications that have been proposed. It seems to me that in that way, and in that way only, can we hope finally to reach a result whereby our specifications will be generally recognized as being in fact as well as in name, "Standard American Specifications."

Mr. Kent. WM. KENT.—I heartily agree with what Mr. Marburg has said, and I wish to offer an amendment to Mr. Campbell's motion. He proposes to print our present specifications. I would also have printed in addition the recommendations of the committees of other societies and have our committee instructed to prepare a digest of their conclusions, with a view of reconciling the different specifications, and bringing them into harmony with our own. (This amendment was accepted by Mr. Campbell.)

Mr. Campbell. MR. CAMPBELL.—There seems to be a misconstruction of my remarks or of my motion. One would suppose that I had made a motion that our specifications should never be changed in the indefinite future. My motion only applied to this particular meeting; the amendment does not change the situation at all. All papers on the subject should be in print for our careful study. It would be unwise, however, to introduce any new matter without thorough investigation.

Mrr. Iob. ROBERT JOB.—The discussion shows conclusively that a number of important changes have been made and proposed in

our standard specifications since those of our Society were adopted several years ago, and I, for one, shall heartily endorse the plan of having these specifications submitted to the committee for their revision in accordance with the best standard practice. I think this the only right course in view of the general discussion within the past few years. Mr. Job.

G. Lanza.—The principle has been repeatedly acknowledged that our specifications are to be constantly modified as fast as new light appears upon the subjects; hence we ought to be always ready to consider any proposed changes. Mr. Lanza.

Moreover, it is not sufficient that Committee A have laid before them certain modifications to be considered and that they report back to the Society that they recommend or do not recommend their adoption. It seems to me that Committee A should be instructed by the Society to take up and discuss at least the more important of the modifications reported by other societies, and to give us the reasons for whatever recommendations they present.

As an instance, two years ago in this room we had a very earnest discussion which turned on the question of heat treatment. At that time there was objection to making modifications immediately. It was stated by certain steel makers, that there was not enough known about it, and I remember very well that some of the steel makers stated that they would know more about it very shortly. It seems to me that they ought to be able to report something in detail by this time, but we have to-day, two years later, coming up before us from engineers and engineering societies the same questions, and nothing has been done by us, notwithstanding that our attention was called to it two years ago, and that others are already making demands upon the steel maker for the purpose of insuring proper heat treatment.

It seems to me that this society should discuss the question of heat treatment as it comes up to-day, or else, that it give to Committee A instructions to discuss it and to report the pros and cons in favor of or against any recommendations they may make.

Mr. Job.—It seems to me if a report is to be made upon this subject at our next meeting next year it would be a good plan to have the data sent to each member of the society prior to the meeting in order that we might have all the facts that are at hand and know just exactly what has been done and what recommenda- Mr. Job.

Mr. Job.

tions are to be made, and thus be in a position to act intelligently at the meeting.

Mr. Metcalf.

WILLIAM METCALF.—I am not a manufacturer of structural steel and I am not an engineer of structures, but there has been a great deal said in which I am vitally interested; two or three points that strike me very forcibly. One is that according to my experience in life, the best thing a manufacturer can do is to find out what the other fellow wants and give it to him. Another thing is, that I vastly prefer to work to specification when I can get one, because when I fill that my responsibility ceases.

In regard to revising the specifications, in consideration of what the President said so beautifully and forcibly last night, it strikes me that it is worth while for us to consider whether we might not possibly be running our heads against a stone wall. There is a society of engineers of maintenance of way. When they make recommendations, and the chief men of their organizations or railroads say we adopt your recommendations, that is what the manufacturers have to got make, whether they like it or not. If we don't consider that we may simply run our heads against a stone wall and get up a specification that will be of no use to anybody.

With regard to the question of heat treatment, I don't believe there is a manufacturer who does not know all about it; it is the other fellows who are to find out what they ought to compel us to do if they can, to get the best heat treatment.

The question as it strikes me could be reduced to very simple limits, and that is that all these matters be referred back to Committee A, with instructions to examine them thoroughly and report later.

Mr. Royal.

JOSEPH ROYAL.—It would appear to me that the motion and amendment may lead to endless argument and discussion, and I should think, as Mr. Metcalf has said, a simple resolution would facilitate matters. The most important specifications that this Society can promulgate are specifications for iron and steel. Therefore, it might be the part of wisdom to refer this question back to the committee with instructions to consult with all the leading engineering societies in the country, and endeavor to present to us at our next annual meeting specifications acceptable to all knowing it is satisfactory to all these engineering societies. The report

might be printed in advance with comments, so that all the members may know in advance of the meeting the probable text of the discussion. I find it very unsatisfactory to come to these meetings to listen to papers that one is to a certain extent practically unprepared to discuss. Mr. Royal.

Mr. Webster.—I would say that we have been consulting with other committees and other societies for three years. Our committee has taken a firm stand, however, that they will not consider any modifications. If the Society thinks we should consider modifications and decide them on their merits, let the matter be referred back to us and we will take our own means and time for doing so. As to printing a mass of stuff on the subject, I don't think I thall have time to attend to that, and I know Mr. Marburg, the Secretary, will not have the time. Mr. Webster

Mr. Marburg.—I should like to call attention to the fact that our last volume of proceedings contains all the leading specifications recently recommended. Mr. Colby's paper, for example, gives a detailed comparison of the important points of difference in specifications in convenient tabulated form, and those members directly interested have had an opportunity all this time to post themselves thoroughly on the points in question. Mr. Marburg.

I want to second heartily what Mr. Webster has said. It would be impracticable, considering our resources, to attempt to issue a mass of data of this sort that is of direct interest to only a comparatively small portion of our large membership, Again, there is the question of discriminating between what may be regarded as essential and non-essential points. That has to be entrusted to somebody, and the committee would seem to be the body to whom it should be entrusted. Therefore, I think a brief resolution to the effect that Committee A be instructed to give careful consideration to the recommendations of other societies, and to make a detailed report on all important points of difference will meet the situation adequately. This report should, of course, be printed for advance distribution.

Mr. Campbell.—I withdraw my original motion, and move that the matter be referred to Committee A, with instructions to send out their recommendations in printed form, with a majority and a minority report, before the next annual meeting. (This motion was duly seconded and carried). Mr. Campbell.

REPORT OF COMMITTEE "B" ON STANDARD SPECIFICATIONS FOR CAST IRON AND FINISHED CASTINGS.

Introduction by Walter Wood, Chairman.

In laying before the meeting the results of the work of the sub-committees in the form of the proposed Standard Specifications for Cast Iron and Finished Castings, there is little to add, except to call attention to the fact that care was taken in forming these sub-committees to appoint on them men prominent in each specialty covered by these specifications.

Each committee in doing its work followed the same general plan, namely, to discuss among themselves, either at a personal meeting or by correspondence, the general form, details and features of the specifications. As each specification was completed the final result was referred as a whole to each member of the committee, and the result reached was as nearly unanimous as could be expected where men of strong individuality compare and adjust differences of views.

It is hoped that the committees which have as yet not been able to report, namely, those on "Influence of the Addition of Special Metals to Cast Iron," and "Micro-Structure of Cast Iron," will, as time goes on, be able to lay before the Society interesting facts on these two important subjects, which really lie at the foundation of the intelligent study of the physics of cast iron, and this, after all, is the basis upon which practical results must rest.

The International Association expecting to meet in St. Petersburg in August of this year, the President requested that all matters to be brought before that Congress should be in his hands by January 15. Copies of the specifications now before you were therefore duly forwarded to President Tetmajer. It is hoped that the postponement of the Congress on account of the war will permit a full discussion of these specifications by our foreign associates, so that when the next Congress meets, it will be possible to reach some definite conclusion as to International Specifications.

The drafting of Standard Specifications naturally brings into harmony various thoughts and suggestions, all of which are good and lead to practical results, and which probably only need to be reduced to a system for the sake of reaching the desirable end, viz.:—a uniformity of methods. In addition to this general purpose, the committees have had in mind two most important points:

1. To establish an intelligent standard for the purchase and sale of pig iron, and thus to abandon the old-fashioned way of grading the metal from its appearance.

2. To adopt a standard test-bar, and to fix the manner in which it shall be made and tested. The Committee has furnished a measure to which the test-bars now in use throughout the various trades can be referred.

If nothing farther had been accomplished, the work of the committees would have been most useful. They have gone farther, however, and have covered quite thoroughly the whole field of Cast Iron and Finished Castings.

PROPOSED STANDARD SPECIFICATIONS FOR FOUNDRY PIG IRON.

Analysis.

It is recommended that all purchases be made by analysis.

Sampling.

In contracts where pig iron is sold by chemical analysis, each carload, or its equivalent, shall be considered as a unit. At least one pig shall be selected at random from each two tons of every carload, and so as to fairly represent it.

Drillings shall be taken so as to fairly represent the fracture surface of each pig, and the sample analyzed shall consist of an equal quantity of drillings from each pig, well mixed and ground before analysis.

Allowances and Penalties

In all contracts in the absence of a definite understanding to the contrary, a variation of 10 per cent. of silicon, either way, and of 0.01 in sulphur above the standard is allowed. A deficiency of over 10 per cent. in the silicon, up to 20 per cent., and a further increase in sulphur up to 0.01 over the above allowance, subject the shipment to a penalty of 1 per cent. in the price for each element so affected.

Base Analysis of Grades.

In the absence of specifications the following numbers, known to the trade, shall represent the appended analyses for standard grades of foundry pig iron, irrespective of the fracture, and subject to allowances and penalties as above:

Grade.	Per Cent. Silicon.	Per Cent. Sulphur.
No. 1	2.75	0.035
No. 2	2.25	0.045
No. 3	1.75	0.055
No. 4	1.25	0.065

DISCUSSION.

Richard Moldenke.—In the discussion of the proposed pig iron specifications at the meeting of the American Foundrymen's Association, it was pointed out that the selection of one pig to represent every two tons of pig iron was burdensome, and would not be observed. One pig for every four tons was suggested as amply sufficient. Then the penalty exacted was considered entirely too low. The foundryman feels that with a 10 per cent. variation in the silicon from the standard he can get along well enough. When, however, a second 10 per cent. is added, and only 1 per cent. of the value sacrificed by the furnaceman, then he in reality gets an iron one grade number lower, and pays only seventeen to twenty cents less therefor, which is not in accordance with market conditions. The foundrymen therefore, request a modification of the specifications to the effect that when the second drop of 10 per cent. in the silicon takes place, the acceptance of the iron be made optional, and the penalty be 4 per cent. of the selling price. Mr. Moldenke

In the discussion the further question was asked why only silicon and sulphur were specified, and not manganese, phosphorus, etc. The explanation was given that the latter elements were really a question of brand, certain furnaces having their irons always with given and well recognized percentages of the latter elements. Silicon and sulphur, however, were a matter of grade, and hence should be specified carefully.

A further question was that of possible oxidation. It was pointed out that this might be the cause why charcoal irons and the coke varieties, all of identical composition, give such different strengths in the castings made from them. We have as yet much to learn in this respect.

B. F. Fackenthal, Jr.—What about the price? Mr. Fackenthal

Mr. Moldenke.—The price would not matter so much in this instance, if the penalty be made sufficiently protective. The foundryman would say: "All right, the iron is in my yard, and I Mr. Moldenke

Mr. Moldenke. will keep it, but I will make my settlement on a basis of so many cents a ton reduction." When the price of pig iron is very high the 4 per cent. penalty is more than the difference in grade price, but it is just then that the foundryman needs the protection.

Mr. Kent. WM. KENT.—I would like to ask an explanation as to the amount of penalty. The language does not seem to me to be clear. It reads, "Up to 20 per cent." What would happen if it were over 20 per cent?

Mr. Moldenke. MR. MOLDENKE.—After 20 per cent. the iron is rejected absolutely.

Mr. Kent. MR. KENT.—It should then be so stated.

Mr. Wood. WALTER WOOD.—That question was talked over at the Delaware Water Gap Meeting, and the claim was made that the furnace-men ought to have some limit, up to which they can insist on the iron being accepted, and the customer ought to have some limit at which he can stop the acceptance, and that 20 per cent. was a proper limit at which the discussion should begin. It is hardly fair to either the furnacemen or foundrymen to say the metal shall be rejected. That should be left to the option of the seller and buyer.

Mr. Kent. MR. KENT.—If beyond 20 per cent. the matter is to be left for adjustment; the language should state that.

Mr. Diller. H. E. DILLER.—I should like to say that I think a 4 per cent. provision would be a good one. One per cent. in the present price would be about three dollars for a car load, and it would not pay for the trouble of collecting and proving the correctness of the buyer's analysis. When a firm sells iron they ought to know what they are selling and be able to give what they guarantee up to at least 20 per cent.

Mr. Moldenke. MR. MOLDENKE.—This penalty is really more important than it seems. I believe it is the first of our specifications to embody the idea of either penalty or bonus. The specifications then not only take up the pure matter of testing, but add a commercial utility which will be found of great value to both consumer and producer. This will be further seen in a request to be made to you for the establishment of a committee on specifications for foundry coke. Here also will be a commercial as well as a scientific problem, involving the selection of a standard coke, with bonus and penalty for a variation above or below it.

Mr. Moldenke.—The foundryman usually calls for more silicon than he really requires. The difficulty with the average foundryman is that he does not know how to use the chemistry of the melting process to advantage. After he gets a good low sulphur iron by proper specification, he then deliberately adds more sulphur in the cupola. Until, however, greater care is taken to secure low sulphur coke, and then to melt hot enough, little can be done to remedy this matter. Mr. Moldenke.

The President.—The question of sulphur in pig iron is very important. We have many times examined iron, before it went into the cupola, and then examined castings. If we start with 0.08 per cent. sulphur in the pig iron, we not infrequently find 0.12 or 0.13 per cent. in the castings. Where does this extra sulphur come from? The answer is, from the coke. It is hardly possible to get coke containing less than 0.75 per cent. of sulphur, and if the calculation is made on the supposition that seven pounds of metal are melted by a pound of coke, and that the largest portion of the sulphur in the fuel goes into the metal, it is easy to see where the extra 0.10 per cent. of sulphur comes from. If now we start with 0.06 or 0.08 per cent. or 0.10 per cent. of sulphur in the pig metal, it is easy to see what we will get in the castings. The President.

Does any one know that 0.30 per cent. of sulphur in a finished casting is detrimental, or what is the real successful limit of sulphur in cast iron? We are quite familiar with the common beliefs, but has any one sufficiently demonstrated this point to enable him to be dogmatic?

J. A. Kinkead.—In the problems of cast iron, there are so many variables that one cannot adjust them all. The question of sulphur alone depends in part on the size of the casting. We had a cylinder head one day which could not be machined, showing 0.22 per cent. sulphur, but other castings from the same ladle gave no trouble and the analysis of the day's run was normal. Mr. Kinkead.

The sulphur proposition came to me recently from a railroad company, they asking for cast iron wheel centers with not over 0.03 per cent. sulphur, while none of the pig irons on the market that could be used contained less than a guaranteed 0.03 per cent. and the coke was also high in sulphur in that market.

Mr. Moldenke.—Mr. Kincaid is perfectly correct. It is one of the conditions which usually surround the foundry. Nearly Mr. Moldenke.

Mr Moldenke. all of them have machine shops attached. Every time there is a hard casting, there is trouble. The difficulty is not so much from the additional 0.02 per cent sulphur itself, but from the effect that this sulphur has on the carbon content. The more this carbon is kept in the combined state, as a result of the presence of greater quantities of sulphur, the harder will be the casting.

The President. THE PRESIDENT.—It seems apparent in the present state of our knowledge in regard to pig iron and the influence of the various substances contained in the metal on it, that fine distinctions cannot be made. What we want to decide on is a fairly reasonable, workable specification, which will undoubtedly be subject to modification from year to year.

Mr. Wood. MR. WOOD.—The specification for pig iron starts out, as you all notice, with the recommendation that pig iron be always bought by analysis. The analyses with which the specifications close are simply tentative, until the small foundryman becomes accustomed to buying by analysis. Buying by analysis was put in the specifications as a departure from the old practice of buying by number. It was thought by the committee that the small table of analyses at the bottom would eventually cease to exist.

Mr. West. T. D. WEST.—Are we to accept these specifications for one year only? My idea in asking that, is, that while the numbering of the grades shown is in the right line, it hardly comes up to what I would like to see adopted. I know from experience, that a variation of 0.25 per cent. in silicon or 0.030 per cent. in sulphur will affect the iron so that one can generally detect it with a chisel or tool in the machine shop, and I have long advocated the dividing of numbers or grades into ten. But I cheerfully endorse the specifications as they stand, because I believe they are a stepping-stone to something better.

In March, 1901, I presented a paper to the Pittsburgh Foundrymens' Association setting forth the great need of a systematic method of numbering pig iron so that one could form some conception of the grade of any iron by a number. The following table presents the division of grades in ten numbers as advocated, and any one interested can find the whole subject explained and fully discussed on pages 148 to 156 in "Metallurgy of Cast Iron;"

Mr. West.

	No. 1 Iron.	No. 2.	No. 3.	No. 4.
Silicon	2.75 to 3.00	2.50 to 2.75	2.25 to 2.50	2.00 to 2.25
Sulphur	.01 to .04	.01 to .04	.01 to .04	.01 to .04

	No. 5.	No. 6.	No. 7.	No. 8.
Silicon	1.75 to 2.00	1.50 to 1.75	1.25 to 1.50	1.00 to 1.25
Sulphur	.02 to .05	.02 to .05	.03 to .06	.03 to .06

	No. 9.	No. 10.
Silicon	.75 to 1.00	.50 to .75
Sulphur	.04 to .07	.04 to .10

Mr. Fackenthal.

MR. FACKENTHAL.—At the recent meeting of the American Institute of Mining Engineers I presented my views on the subject of "Chemical Specifications for Pig Iron" rather fully, and I should be glad if that paper could be added to the report of the present discussion as my contribution on the subject.

The motion was made and carried that these specifications be referred back to the committee for modification in accordance with the discussion, and that they be then transmitted to the Executive Committee with power to refer them to letter-ballot.*

*The revised specifications, which were adopted by letter-ballot on November 15, 1904, appear on pp. 103-104.—ED.

CHEMICAL SPECIFICATIONS FOR PIG IRON.*

By B. F. Fackenthal, Jr.

The manufactureres of merchant pig-iron can congratulate themselves that foundry-men are slowly but surely recognizing the fact that their mixtures should be made up according to chemical analyses, rather than by fracture; but in my experience many foundries ordering specification-iron want the grading by fracture also. They want both the penny and the cake.

One of the largest customers of the Thomas Iron Co., who uses thousands of tons of Thomas iron yearly, always buys "No. 2 plain," stipulating for shipments from the lower pig-beds when we can furnish them. Being an old furnace-manager, he knows that the iron in the lower beds, having traveled farther from the furnace, cooling as it warmed the greater length of runner, solidifies sooner in the beds, and thus presents a closer grain; whereas, the iron of the upper beds, remaining longer liquid, will exhibit after solidification a fracture of higher grade, though the two may be identical in composition. In other words, No. 2 plain iron from the lower beds may be just as good in the cupola as No. 2X of the same cast from the upper beds, while it is cheaper, when the price is determined by grade, and the grade by fracture. This founder has no laboratory; but his practical knowledge of the conditions of the pig-bed has enabled him, for many years, to save the difference of price (at least 50 cents per ton) between No. 2 plain and No. 2X on a considerable proportion of the iron he has bought. Since classifying by analysis instead of fracture would put the No. 2 plain of lower pig-beds in the same class with the higher-priced No. 2X of the same cast and composition, it is no wonder that, as a buyer of superior shrewdness, he prefers the old method.

Yet classifying by analysis, which is in such cases and in other ways often advantageous to the furnace-man, ought to be preferred by the founder, because it would enable him to calculate his mixtures with certainty. For there are both tricks of nature and tricks of the trade which may make the grading by fracture unfavorable and misleading to the consumer; and, after all, the most advantageous arrangement for both parties is that which is just to each. Unquestion-

* This paper is reprinted from advance sheets of Vol. XXXV of the Transactions of the American Institute of Mining Engineers, as an interesting contribution to the preceding discussion on Standard Specifications for Foundry Pig Iron.—Ed.

ably, such an arrangement should be based upon a common knowledge of the composition of the pig-iron concerned; and this knowledge requires of the founder the determination of mixtures for the cupola, based on chemical data. This, however, will be of but little value to the founder who permits his application of chemistry to stop there and does not carry it also to the floor of his foundry, by regular tests of his castings. But some founders are not yet willing to take this trouble; and, as a consequence, they cannot locate the cause of unsatisfactory castings. Often they complain of the pig-iron, when this was entirely suitable, but was spoiled in re-melting. The following examples from my record of analyses may serve as illustrations:

1. Complaint was made that a car-load of No. 2X Thomas iron produced hard castings, when soft ones were desired, and were reasonably to be expected from that grade of pig. The customer returned two pigs, marked respectively "hard" and "soft," and two samples of the unsatisfactory hard castings. These four samples were analyzed in the Hokendauqua laboratory, with the following results:—

	Hard Pig. Per Cent.	Soft Pig. Per Cent.	Casting. Per Cent.	Casting. Per Cent.
Silicon, . .	. 2.680	2.633	2.327	2.257
Sulphur,. .	. 0.022	0.023	0.263	0.249

The Thomas Iron Company's sampling of the entire car-load, prior to shipment, showed silicon 2.61 and sulphur 0.022 per cent. It is unusual for the analyses of selected pigs returned to the laboratory to correspond so closely to those of the furnace sampling. The "hard" pig was doubtless chilled in the runner and, therefore, not as open-grained as the "soft" one; but they doubtless came from the same cast, and possibly from the same bed. If the founder had bought by analysis and not by fracture, he would have preferred the "hard" pig, since it was slightly higher in silicon, and slightly lower in sulphur than the "soft" one. The castings sent for analysis contained about twelve times as much sulphur as the original pig-iron, and the founder's difficulty was certainly due to bad cupola-practice. The excessive amount of sulphur in the castings may have been due partly to fuel high in sulphur, and perhaps partly to improper fluxing, but more probably to the use of too little fuel in re-melting the iron. The loss of silicon during the re-melting was about 13.8 per cent., which shows fairly good practice in this respect.

2. Another customer, who complained that Thomas No. 2X iron gave him bad results, returned six pigs and a hard casting. The analyses of these samples, also the analysis of the pig-iron before it was shipped are as follows:—

	Furnace Sampling of Car-Load Per Cent.	Six Pigs Returned. Per Cent.	Hard Casting. Per Cent.
Silicon,	2.70	2.854	2.257
Sulphur,	0.017	0.052	0.319
Phosphorus,	....	0.812	0.800
Manganese	....	0.403	0.291

Loss of silicon on re-melt about 20 per cent.

In this instance the pigs returned were much higher in sulphur, but the cause of complaint was doubtless the same as in the former instance, viz.: too much sulphur was allowed to be taken up in the cupola. A few more pounds of fuel would have corrected the difficulty and kept the sulphur out of the castings. The same customer reported that a previous shipment of iron, containing silicon, 2.40; sulphur, 0.041; and phosphorous, 0.736 per cent., gave him entirely satisfactory results. I could give many examples of this kind, but these two are sufficient.

Many foundry-men call for high silicon iron; and if the results are not satisfactory, they seem to think that still higher silicon would correct the evil. Our experience, however, is that, in many instances, the silicon specified was already too high, and that they required iron lower, not higher, in this element.

3. A complaint was made of Thomas No. 2X iron on account of the blow-holes it contained, which, the founder said, were reproduced in his castings. The iron made at that time in one of our furnaces did, in fact, contain an unusual number of blow-holes, and we experienced great difficulty in locating the trouble, which was finally traced to the quality of the sand used for the pig-bed. The founder sent us four samples of borings, two from the pig-iron and two from the castings, which gave the following analyses:—

	Pig-Iron, Solid Part. Per Cent.	Pig-Iron, Side of Blow-Holes. Per Cent.	Castings, Solid Part. Per Cent.	Castings, Side of Blow-Holes. Per Cent.
Silicon,	2.608	2.617	1.778	1.778
Sulphur,	0.029	0.027	0.150	0.129
Phosphorus,	0.836	0.860	0.864	0.852

Loss of silicon in re-melting about 32 per cent.

I cannot see why blow-holes occasioned by bad sand in the pig-bed should be injurious to the iron, or why such blow-holes should be reproduced in the castings. Both in the pig and in the castings the sulphur was lower in the iron around the blow-holes than throughout the solid part of the pig. This is another instance in which the iron was permitted to take up excessive sulphur in the cupola, and, doubtless, goes to show that the founder was trusting to the appearance of the pig rather than to its chemical analysis.

4. Three car-loads of pig-iron shipped by rail were delivered to the

wrong customers: a puddling-furnace receiving No. 2 plain, intended for a pipe-foundry; the pipe-foundry receiving a car of No. 2X intended for a pump-works; and the pump-works receiving the car of gray-forge intended for the puddling-mill. All these shipments were received and used without complaint. In these cases the fracture could not have been taken into account by the customers.

5. To a customer operating puddling-furnaces, who always specified open iron, there was shipped by mistake a car of silver-gray iron, containing 6.38 per cent. of silicon, made while blowing-in a furnace. He reported that particular car-load as having given very satisfactory results; and for some time thereater he referred to this shipment and wanted more like it. The iron was open-grained, and the appearance suited him. I have often wondered whether he used it alone or in mixture with some other iron that happened to be particularly low in silicon,.

6. Some years ago, visiting a furnace-plant in the Birmingham district, Alabama, I found that special efforts were being made to keep the iron in the pig-beds hot for as long a time as possible, by covering it with sand to the depth of 6 or 8 inches. It was claimed that this annealing process toughened the iron and permitted the segregation of an additional amount of graphitic carbon. On my return home, believing that I had learned something of great value, I tried the experiment at the Durham furnace, of which I was manager at that time, with the result that after the iron was cool it was impossible to break the pigs from the sows by sledge-hammers or other ordinary means. The pig-iron was finally dragged out of the cast-house with a team of horses, one bed at a time, and the entire force of blacksmiths was used to cut it apart with cold-cutters. No further attempt to improve the fracture was made.

I will close these remarks by giving the following statement of interesting experiments, made in the cupola of a large foundry, to show the losses of silicon in re-melting, as affected by the presence of manganese:—

Sample No.	Manganese. Per Cent.	Per Cent. of Total Silicon. Lost in Re-melting.
1,	0.04	34
2,	0.20	23
3,	0.43	12
4,	0.53	4

I am not at liberty to give the brands of iron, except to say that Sample No. 3 was Thomas iron.

SPECIFICATIONS FOR CAST IRON AND FINISHED CASTINGS.*

By Richard Moldenke.

In following the discussion on the specifications for cast-iron and finished castings, I was strongly impressed with two points which might be ventilated to advantage more fully from the view of the practical foundryman. First, the reasons why only silicon and sulphur were specified and not phosphorus, manganese and carbon; and second, why but little was said concerning the presence of iron oxide in the material.

With regard to the first point, the modern foundryman always demands a full analysis of the pig-iron on which he is figuring with the seller; yet, when the order is placed, only the silicon and sulphur contents of the pig-iron are of importance.

Concerning the presence of phosphorus, all the pig-iron made for foundry purposes is divided into three classes, namely, containing less than 0.4 per cent.; between 0.4 and 0.8 per cent., and more than 0.8 per cent. In all of these three classes a choice is to be had of the silicon and sulphur contents. The pig-irons containing the lowest ranges of phosphorous will be used for making special grades of gun-iron, car-wheels and specification-castings; and to the foundryman it is immaterial whether the phosphorus present is a mere trace or 0.4 per cent., provided it be not above the latter limit. If ordinary classes of jobbing work, machinery, and gray-iron castings in general, pig-iron containing the medium percentage of phosphorus is desired, and in this case also it is not important whether the phosphorus-content be at the upper or at the lower limit, provided it does not go beyond either. Finally, for art work, stoves, and novelty castings, or those in which great fluidity of the metal is required, the high range in phosphorus is selected, and it matters little how high this range is, for the reason that any great discrepancy will be adjusted by proper mixing before melting. Furthermore, the customs of the trade are such that no pig-iron merchant would think of selling a high phosphorous pig-iron to the maker of boiler-castings, which are tested under pressure, and, therefore, might endanger life. The stove manufacturers have learned to use certain pig-irons high in phosphorus, and would not

*This paper is reprinted from advance sheets of Vol. XXXV of the Transactions of the American Institute of Mining Engineers, as an interesting contribution to the preceding discussion on Standard Specifications for Foundry Pig Iron.—Ed.

think of going outside of this class of metal; consequently, the element phosphorus is not so all-important in foundry-practice as it is in making steel; and, as a result, it was not deemed necessary to burden the general specifications for the sale of pig-iron with the phosphorus requirements.

A similar condition of affairs exists with regard to the quantity of manganese present in pig-iron. In this case there are two classes of metal; the line of division being 0.8 per cent, of manganese. Pig-irons containing a percentage of manganese less than 0.8 per cent are valuable for making ordinary foundry-castings; while those pig-irons exceeding 0.8 per cent. manganese will be sought for making special castings on account of their high manganese-content.

The founder, in glancing over the analyses presented by the agents of the various pig-iron manufacturers, will at once remove from all consideration those furnaces which make iron too high or too low in phosphorous, or too high in manganese for his use and his selection will be made from the rest according to the silicon and sulphur contents of the metal.

Finally, as to the carbon, if anything, the foundryman reduces the quantity present in the pig-iron by the addition of scrap-steel in the melting-process. Therefore, but little attention is paid to the total carbon-content of American pig-irons, which is almost invariably present in proper proportion. For special castings, however, which require undue softness, a high percentage of total-carbon is sought, A pig-iron containing a carbon-content below the normal arouses suspicion, and indicates that something has been wrong at the furnace. If an occasional specification is seen asking for a given percentage of total-carbon, it is probably necessary for a given purpose. On the other hand, a specification (and I have seen several) demanding more than a given minimum of graphite is an evidence of ignorance, and the furnaceman can only hope that some day the maker of a specification of this kind will learn more of foundry metallurgy and withdraw the useless and objectionable requirement.

Taking up the second point of importance,—the oxidation of the metal,—the lengthy discussion of this subject which took place at the Atlantic City meeting showed that this expression was understood to be the absorption of oxygen from the blast, leaving it in the iron as occluded gas. This effect is not strictly that with which the foundryman has to contend. He is troubled with an actual dissolved iron oxide, and knows that no matter what melting-process he uses, the quantity of this objectionable constituent is sure to be increased at every melting.

The steel man is comparatively free from this trouble, because he uses much higher temperatures, and simply adds ferromanganese to remove at once any oxidation products in the bath of metal. Suppose the blow of the converter were interrupted at a point where some silicon still remained in the metal, and the metal was then cast into molds, gases would be liberated and a weak product would result.

After all, any foundry melting-process is similar to the converter process, excepting that the blast-pressure is less, the time of action

longer, and no attempt is made to refine the metal. The air-furnace with a top-blast used in the malleable-iron process is practically a converter with a top-blast, instead of one at the bottom or side.

It is my belief that the difference in excellence between cold-blast charcoal-iron, warm-blast charcoal-iron, and hot-blast coke-iron, all of like composition, lies solely in the degree of freedom from oxidation of the metal as it flows from the furnace spout. Foundrymen instinctively realize this effect, and in making special castings the utmost care is taken to get pig-irons which will yield castings of the best service qualities, the composition being constant. Even in the malleable-iron industry, no one who has to make "specification-castings" (specially good work), would think of using straight Bessemer pig-iron for this purpose, even though the chemical composition meets the requirements. The selection will be "Bessemer malleable," or pig-irons with an analysis practically within the Bessemer limit for sulphur, and made of better quality, especially with the aim to avoid weakness, which really means oxidation. I have repeatedly used oridnary "Bessemer" in making malleable castings, with the result that the tensile strength was much below the average. As a result of this experience, I used the pig-iron only from those blast-furnaces which look after these matters more closely and make a more satisfactory product.

What the foundryman fears most, in using the open-hearth furnace for his work, is the occasional rising of pieces of the furnace-bottom which are saturated with burnt iron, and oxidation products. These pieces float on the surface of the bath of metal and gradually yield to it the iron oxide contained, with the result that the metal in the bath, though of proper chemical composition, loses its life as soon as tapped, and "skulls" everything into which it flows.

Foundrymen know that the pig-iron they use, be it as good as it can be made, is never improved in the melting. Even the best of them would be glad to do better work, if they knew how to do it. The most pressing need at present is the assurance that they are getting the best pig-iron that can be made for a given composition, and that the blast-furnaces also are trying continually to improve their work. If both foundryman and furnaceman will keep this improvement always in mind, there is nothing to fear for the future, and in time we may be able to correct irregularities which are now beyond our knowledge.

PROPOSED STANDARD SPECIFICATIONS FOR CAST-IRON PIPE AND SPECIAL CASTINGS.

Description of Pipes.

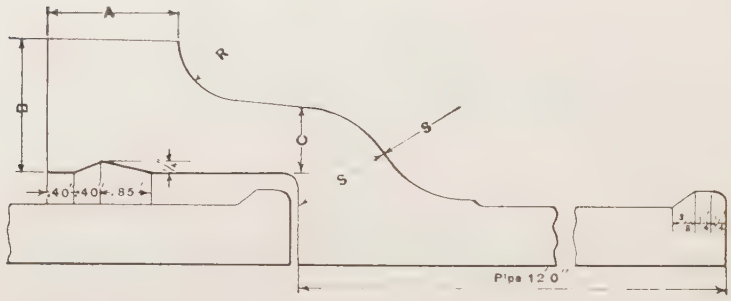
Section 1. The pipes shall be made with hub and spigot joints, and shall accurately conform to the dimensions given in Tables Nos. 1 and 2. They shall be straight and shall be true circles in section, with their inner and outer surfaces concentric, and shall be of the specified dimensions in outside diameter. They shall be at least 12 feet in length, exclusive of socket. For pipes of each size from 4-inch to 24-inch, inclusive, there shall be two standards of outside diameter, and for pipes from 30-inch to 60-inch, inclusive, there shall be four standards of outside diameter, as shown by Table No. 2.

All pipes having the same outside diameter shall have the same inside diameter at both ends. The inside diameter of the lighter pipes of each standard outside diameter shall be gradually increased for a distance of about 6 inches from each end of the pipe so as to obtain the required standard thickness and weight for each size and class of pipe.

Pipes whose standard thickness and weight are intermediate between the classes in Table No. 2 shall be made of the same outside diameter as the next heavier class. Pipes whose standard thickness and weight are less than shown by Table No. 2 shall be made of the same outside diameter as the Class A pipes, and pipes whose thickness and weight are more than shown by Table No. 2 shall be made of the same outside diameter as the Class D pipes.

For pipes 4-inch to 12-inch, inclusive, one class of special castings shall be furnished, made from Class D pattern. Those having spigot ends shall have outside diameters of spigot ends midway between the two standards of outside diameter as shown by Table No. 2, and shall be tapered back for a distance of 6 inches. For pipes from 14-inch to 24-inch, inclusive, two classes of special castings shall be furnished, Class B special castings with Classes

TABLE NO. 1.—GENERAL DIMENSIONS OF PIPES.



Nominal Diam. Inches.	Classes.	Actual Outside Diam. Inches.	Diam. of Sockets.		Depth of Sockets.		A	B	C
			Pipe. Inches.	Special Castings. Inches.	Pipe. Inches.	Special Castings. Inches.			
4	A—B	4.80	5.60	5.70	3.50	4.00	1.5	1.30	.65
4	C—D	5.00	5.80	5.70	3.50	4.00	1.5	1.30	.65
6	A—B	6.90	7.70	7.80	3.50	4.00	1.5	1.40	.70
6	C—D	7.10	7.90	7.80	3.50	4.00	1.5	1.40	.70
8		9.05	9.85	10.00	4.00	4.00	1.5	1.50	.75
8	C—D	9.30	10.10	10.00	4.00	4.00	1.5	1.50	.75
10	A—B	11.10	11 90	12.10	4.00	4.00	1.5	1.50	.75
10	C—D	11.40	12.20	12.10	4.00	4.00	1.5	1.60	.80
12	A—B	13.20	14.00	14.20	4.00	4.00	1.5	1.60	.80
12	C—D	13.50	14.30	14.20	4.00	4.00	1.5	1.70	.85
14	A—B	15.30	16.10	16.10	4.00	4.00	1.5	1.70	.85
14	C—D	15.65	16.45	16.45	4.00	4.00	1.5	1.80	.90
16	A—B	17.40	18.40	18.40	4.00	4.00	1.75	1.80	.90
16	C—	17.80	18.80	18.80	4.00	4.00	1.75	1.90	1.00
18	A—B	19.50	20.50	20.50	4.00	4.00	1.75	1.90	.95
18	C—D	19.92	20.92	20.92	4.00	4.00	1.75	2.10	1.05
20	A—B	21.60	22.60	22.60	4.00	4 00	1.75	2.00	1 00
20	C—D	22.06	23.06	23.06	4.00	4 00	1.75	2.30	1 15
24	A—B	25.80	26.80	26.80	4.00	4.00	2.00	2.10	1 05
24	C—D	26.32	27.32	27.32	4.00	4.00	2.00	2.50	1 25
30	A	31.74	32.74	32.74	4.50	4.50	2.00	2.50	1.15
30	B	32.00	33.00	33.00	4.50	4.50	2.00	2.30	1.15
30	C	32.40	33.40	33.40	4.50	4.50	2.00	2.60	1.32
30	D	32.74	33.74	33.74	4.50	4.50	2.00	3.00	1.50
36	A	37.96	38.96	38.96	4.50	4.50	2.00	2.50	1.25
36	B	38.30	39.30	39.30	4.50	4.50	2.00	2.80	1 40
36	C	38.70	39.70	39.70	4.50	4.50	2.00	3.10	1.60
36	D	39.16	40.16	40.16	4.50	4.50	2.00	3.40	1.80
42	A	44.20	45.20	45.20	5.00	5.00	2.00	2.80	1.40
42	B	44.50	45.50	45.50	5.00	5.00	2.00	3.00	1.50
42	C	45.10	46.10	46.10	5.00	5.00	2.00	3.40	1.75
42	D	45.58	46.58	46.58	5.00	5.00	2.00	3.80	1.95
48	A	50.50	51.50	51.50	5.00	5 00	2.00	3.00	1.50

TABLE NO. 1.—Continued.

Nominal Diam. Inches.	Classes.	Actual Outside Diam. Inches.	DIAM. OF SOCKETS.		DEPTH OF SOCKETS.		A	B	C
			Pipe. Inches.	Special Castings. Inches.	Pipe. Inches.	Special Castings. Inches.			
48	B	50.80	51.80	51.80	5.00	5.00	2.00	3.30	1.65
48	C	51.40	52.40	52.40	5.00	5.00	2.00	3.80	1.95
48	D	51.98	52.98	52.98	5.00	5.00	2.00	4.20	2.20
54	A	56.66	57.66	57.66	5.50	5.50	2.25	3.20	1.60
54	B	57.10	58.10	58.10	5.50	5.50	2.25	3.60	1.80
54	C	57.80	58.80	58.80	5.50	5.50	2.25	4.00	2.15
54	D	58.40	59.40	59.40	5.50	5.50	2.25	4.40	2.45
60	A	62.80	63.80	63.80	5.50	5.50	2.25	3.40	1.70
60	B	63.40	64.40	64.40	5.50	5.50	2.25	3.70	1.90
60	C	64.20	65.20	65.20	5.50	5.50	2.25	4.20	2.25
60	D	64.82	65.82	65.82	5.50	5.50	2.25	4.70	2.60

A and B pipes, and Class D special castings with Classes C and D pipes, the former to be stamped "AB" and the latter to be stamped "CD." For pipes 30-inch to 60-inch, inclusive, four classes of special castings shall be furnished, one for each class of pipe, and shall be stamped with the letter of the class to which they belong.

ALLOWABLE VARIATION IN DIAMETER OF PIPES AND SOCKETS.

SECTION 2. Especial care shall be taken to have the sockets of the required size. The sockets and spigots will be tested by circular gauges, and no pipe will be received which is defective in joint room from any cause. The diameters of the sockets and the outside diameters of the bead ends of the pipes shall not vary from the standard dimensions by more than .06 of an inch for pipes 16 inches or less in diameter; .08 of an inch for 18-inch, 20-inch and 24-inch pipes; .10 of an inch for 30-inch, 36-inch and 42-inch pipes; .12 of an inch for 48-inch, and .15 of an inch for 54-inch and 60-inch pipes.

ALLOWABLE VARIATION IN THICKNESS.

SECTION 3. For pipes whose standard thickness is less than 1 inch the thickness of metal in the body of the pipe shall not be

STANDARD THICKNESSES AND WEIGHTS OF CAST-IRON PIPE.

TABLE NO. 2.

Nominal Inside Diam. Inches.	CLASS A. 100 FT. HEAD. 43 LBS. PRESSURE.			CLASS B. 200 FT. HEAD. 86 LBS. PRESSURE.			CLASS C. 300 FT. HEAD. 130 LBS. PRESSURE.			CLASS D. 400 FT. HEAD 173 LBS. PRESSURE.			Nominal Inside Diam. Inches.
	Thickness. Inches.	Weight per		Thickness. Inches.	Weight per		Thickness. Inches.	Weight per		Thickness. Inches.	Weight per		
		Foot.	Length.		Foot.	Length.		Foot.	Length.		Foot.	Length.	
4	.42	20.0	240	.45	21.7	260	.48	23.3	280	.52	25.0	300	4
6	.44	30.8	370	.48	33.3	400	.51	35.8	430	.55	38.3	460	6
8	.46	42.9	515	.51	47.5	570	.56	52.1	625	.60	55.8	670	8
10	.50	57.1	685	.57	63.8	765	.62	70.8	850	.68	76.7	920	10
12	.54	72.5	870	.62	82.1	985	.68	91.7	1,100	.75	100.0	1,200	12
14	.57	89.6	1,075	.66	102.5	1,230	.74	116.7	1,400	.82	129.2	1,550	14
16	.60	108.3	1,300	.70	125.0	1,500	.80	143.8	1,725	.89	158.3	1,900	16
18	.64	129.2	1,550	.75	150.0	1,800	.87	175.0	2,100	.96	191.7	2,300	18
20	.67	150.0	1,800	.80	175.0	2,100	.92	208.3	2,500	1.03	229.2	2,750	20
24	.76	204.2	2,450	.89	233.3	2,800	1.04	279.2	3,350	1.16	306.7	3,680	24
30	.88	291.7	3,500	1.03	333.3	4,000	1.20	400.0	4,800	1.37	450.0	5,400	30
36	.99	391.7	4,700	1.15	454.2	5,450	1.36	545.8	6,550	1.58	625.0	7,500	36
42	1.10	512.5	6,150	1.28	591.7	7,100	1.54	716.7	8,600	1.78	825.0	9,900	42
48	1.26	666.7	8,000	1.42	750.0	9,000	1.71	908.3	10,900	1.96	1050.0	12,600	48
54	1.35	800.0	9,600	1.55	933.3	11,200	1.90	1141.7	13,700	2.23	1341.7	16,100	54
60	1.39	916.7	11,000	1.67	1104.2	13,250	2.00	1341.7	16,100	2.38	1583.3	19,000	60

The above weights are for 12 feet laying lengths and standard sockets; proportionate allowance to be made for any variation therefrom.

more than .08 of an inch less than the standard thickness, and for pipes whose standard thickness is 1 inch or more, the variation shall not exceed .10 of an inch, except that for spaces not exceeding 8 inches in length in any direction, variations from the standard thickness of .02 of an inch in excess of the allowance above given shall be permitted.

For special castings of standard patterns a variation of 50 per cent. greater than allowed for straight pipe shall be permitted.

Defective Spigots May be Cut.

Section 4. Defective spigot ends on pipes 12 inches or more in diameter may be cut off in a lathe and a half-round wrought-iron band shrunk into a groove cut in the end of the pipe. Not more than 12 per cent of the total number of accepted pipes of each size shall be cut and banded, and no pipe shall be banded which is less than 11 feet in length, exclusive of the socket.

In case the length of a pipe differs from 12 feet, the standard weight of the pipe given in Table No. 2 shall be modified in accordance therewith.

Special Castings.

Section 5. All special castings shall be made in accordance with the cuts and the dimensions given in the table forming a part of these specifications.

The diameters of the sockets and the external diameters of the bead ends of the special castings shall not vary from the standard dimensions by more than .12 of an inch for castings 16 inches or less in diameter; .15 of an inch for 18-inch, 20-inch and 24-inch; .20 of an inch for 30-inch, 36-inch and 42-inch, and .24 of an inch for 48-inch, 54-inch and 60-inch. These variations apply only to special castings made from standard patterns.

The flanges on all manhole castings and manhole covers shall be faced true and smooth, and drilled to receive bolts of the sizes given in the tables. The manufacturer shall furnish and deliver all bolts for bolting on the manhole covers, the bolts to be of the sizes shown on plans and made of the best quality of mild steel, with hexagonal heads and nuts and sound, well-fitting threads.

MARKING.

SECTION 6. Every pipe and special casting shall have distinctly cast upon it the initials of the maker's name. When cast especially to order, each pipe and special casting larger than 4-inch may also have cast upon it figures showing the year in which it was cast and a number signifying the order in point of time in which it was cast, the figures denoting the year being above and the number below, thus:

1901	1901	1901
1	2	3

etc., also any initials, not exceeding four, which may be required by the purchaser. The letters and figures shall be cast on the outside and shall be not less than 2 inches in length and $\frac{1}{8}$ of an inch in relief for pipes 8 inches in diameter and larger. For smaller sizes of pipes the letters may be 1 inch in length. The weight and the class letter shall be conspicuously painted in white on the inside of each pipe and special casting after the coating has become hard.

ALLOWABLE PERCENTAGE OF VARIATION IN WEIGHT.

SECTION 7. No pipe shall be accepted the weight of which shall be less than the standard weight by more than 5 per cent for pipes 16 inches or less in diameter, and 4 per cent for pipes more than 16 inches in diameter, and no excess above the standard weight of more than the given percentages for the several sizes shall be paid for. The total weight to be paid for shall not exceed for each size and class of pipe received the sum of the standard weights of the same number of pieces of the given size and class by more than 2 per cent.

No special casting shall be accepted the weight of which shall be less than the standard weight by more than 10 per cent for pipes 12 inches or less in diameter, and 8 per cent for larger sizes, except that curves, Y pieces and breeches pipe may be 12 per cent below the standard weight, and no excess above the standard weight of more than the above percentages for the several sizes will be paid for. These variations apply only to castings made from the standard patterns.

Quality of Iron.

Section 8. All pipes and special castings shall be made of cast iron of good quality, and of such character as shall make the metal of the castings strong, tough and of even grain, and soft enough to satisfactorily admit of drilling and cutting. The metal shall be made without any admixture of cinder iron or other inferior metal, and shall be remelted in a cupola or air furnace.

Tests of Material.

Section 9. Specimen bars of the metal used, each being 26 inches long by 2 inches wide and 1 inch thick, shall be made without charge as often as the engineer may direct, and, in default of definite instructions, the contractor shall make and test at least one bar from each heat or run of metal. The bars, when placed flatwise upon supports 24 inches apart and loaded in the center, shall for pipes 12 inches or less in diameter support a load of 1,900 pounds and show a deflection of not less than .30 of an inch before breaking, and for pipes of sizes larger than 12 inches shall support a load of 2,000 pounds and show a deflection of not less than .32 of an inch. The contractor shall have the right to make and break three bars from each heat or run of metal, and the test shall be based upon the average results of the three bars. Should the dimensions of the bars differ from those above given, a proper allowance therefor shall be made in the results of the tests.

Casting of Pipes.

Section 10. The straight pipes shall be cast in dry sand molds in a vertical position. Pipes 16 inches or less in diameter shall be cast with the hub end up or down, as specified in the proposal. Pipes 18 inches or more in diameter shall be cast with the hub end down.

The pipes shall not be stripped or taken from the pit while showing color of heat, but shall be left in the flasks for a sufficient length of time to prevent unequal contraction by subsequent exposure.

Quality of Castings.

Section 11. The pipes and special castings shall be smooth, free from scales, lumps, blisters, sand holes and defects of every

nature which unfit them for the use for which they are intended. No plugging or filling will be allowed.

CLEANING AND INSPECTION.

SECTION 12. All pipes and special castings shall be thoroughly cleaned and subjected to a careful hammer inspection. No casting shall be coated unless entirely clean and free from rust, and approved in these respects by the engineer immediately before being dipped.

COATING.

SECTION 13. Every pipe and special casting shall be coated inside and out with coal-tar pitch varnish. The varnish shall be made from coal tar. To this material sufficient oil shall be added to make a smooth coating, tough and tenacious when cold, and not brittle nor with any tendency to scale off.

Each casting shall be heated to a temperature of 300° F. immediately before it is dipped, and shall possess not less than this temperature at the time it is put in the vat. The ovens in which the pipes are heated shall be so arranged that all portions of the pipe shall be heated to an even temperature. Each casting shall remain in the bath at least five minutes.

The varnish shall be heated to a temperature of 300° F. (or less if the engineer shall so order), and shall be maintained at this temperature during the time the casting is immersed.

Fresh pitch and oil shall be added when necessary to keep the mixture at the proper consistency, and the vat shall be emptied of its contents and refilled with fresh pitch when deemed necessary by the engineer. After being coated the pipes shall be carefully drained of the surplus varnish. Any pipe or special casting that is to be recoated shall first be thoroughly scraped and cleaned.

HYDROSTATIC TEST.

SECTION 14. When the coating has become hard, the straight pipes shall be subjected to a proof by hydrostatic pressure and, if required by the engineer, they shall also be subjected to a hammer test under this pressure.

The pressure to which the different sizes and classes of pipes shall be subjected are as follows:

	20-Inch Diameter and Larger. Pounds per Sq. In.	Less than 20-Inch Diameter. Pounds per Sq. In.
Class A Pipe	150	300
Class B Pipe	200	300
Class C Pipe	250	300
Class D Pipe	300	300

WEIGHING.

SECTION 15. The pipes and special castings shall be weighed for payment under the supervision of the engineer after the application of the coal-tar pitch varnish. If desired by the engineer, the pipes and special castings shall be weighed after their delivery and the weights so ascertained shall be used in the final settlement, provided such weighing is done by a legalized weighmaster. Bids shall be submitted and a final settlement made up on the basis of a ton of 2,000 pounds.

CONTRACTOR TO FURNISH MEN AND MATERIALS.

SECTION 16. The contractor shall provide all tools, testing machines, materials and men necessary for the required testing, inspection and weighing at the foundry of the pipes and special castings; and, should the purchaser have no inspector at the works, the contractor shall, if required by the engineer, furnish a sworn statement that all of the tests have been made as specified, this statement to contain the results of the tests upon the test bars.

POWER OF ENGINEER TO INSPECT.

SECTION 17. The engineer shall be at liberty at all times to inspect the material at the foundry, and the molding, casting and coating of the pipes and special castings. The forms, sizes, uniformity and conditions of all pipes and other castings herein referred to shall be subject to his inspection and approval, and he may reject, without proving, any pipes or other casting which is not in conformity with the specifications or drawings.

INSPECTOR TO REPORT.

SECTION 18. The inspector at the foundry shall report daily to the foundry office all pipes and special castings rejected, with the causes for rejection.

CASTINGS TO BE DELIVERED SOUND AND PERFECT.

SECTION 19. All the pipes and other castings must be delivered in all respects sound and conformable to these specifications. The inspection shall not relieve the contractor of any of his obligations in this respect, and any defective pipe or other castings which may have passed the engineer at the works or elsewhere shall be at all times liable to rejection when discovered until the final completion and adjustment of the contract, provided, however, that the contractor shall not be held liable for pipes or special castings found to be cracked after they have been accepted at the agreed point of delivery. Care shall be taken in handling the pipes not to injure the coating, and no pipes or other material of any kind shall be placed in the pipes during transportation or at any time after they receive the coating.

DEFINITION OF THE WORD "ENGINEER."

SECTION 20. Wherever the word "engineer" is used herein it shall be understood to refer to the engineer or inspector acting for the purchaser and to his properly authorized agents, limited by the particular duties intrusted to them.

DISCUSSION.

WALTER WOOD.—These specifications are largely the out- Mr. Wood.
growth of a practice running through fully forty-five years, hence they contain certain points which might well be eliminated if we were making them entirely new. But when the manufacturers took them up with the water-works engineers, they found a conservatism about changing a phraseology that had been in use so long concerning certain features not observed in present practice.

Two or three such points were brought up at the meeting of the American Institute of Mining Engineers at which these specifications were submitted for discussion.

First. The period the casting should remain in the coating bath. These specifications are distinctly different from practice in that respect. It is thoroughly within the knowledge of all engineers and manufacturers, that although specifications call for the casting to remain in the bath at least five minutes, the practice is to make the period very much shorter,—not more than two or three minutes, and yet the old language is repeated in these specifications.

Second. The question of casting the pipe head up or head down. This also is settled practically by the purchaser having pipe of a certain diameter cast one way and of another diameter another way. This is one of the questions the foundrymen would like to have settled on more definite lines, but the men who buy the castings hesitate to make the change.

Third. The question of uniform outside diameter for all "classes" of pipe was considered an important one, in order that one class of fittings might be applicable to the different weights of the same diameter of pipe. When the question was worked out on mechanical lines, the sizes of the pipe and the different thicknesses were adjusted as shown in the specifications as being the most practical solution so that the castings up to 12 inches (inclusive) in diameter should have one class of fittings.

I think it is evident that for, say, 3-foot pipe it would be im-

Mr. Wood. practicable to use a uniform outside diameter for all classes. We, therefore, divided the fittings for larger sizes into four classes, according to the thickness of the pipe.

The proposed specifications are largely the result of conferences between the New England Water Works Association and the manufacturers who have worked over them for about eighteen months.

Mr. Lanza. G. LANZA.—In the larger pipes the variation of thickness is limited to about 10 per cent., whereas in some of the smaller ones nearly 20 per cent. is allowed.

Mr Wood MR. WOOD.—I think it is only fair to have it understood that these variations of thickness are largely governed by the mode of manufacture. Cast iron pipe is the cheapest form of iron production except pig iron and the manufacture has to be carried on in a way which requires a somewhat wider variation than perhaps theoretically we should wish to allow.

It is found that purchasers prefer somewhat wider limits in order to secure lower prices. With regard to weights, the engineers have taken care of that question by insisting that the total weight of the contract shall be within 2 per cent. of the standard, so that while the limits of each individual pipe are somewhat large, the total limit is very small.

Mr. Kent. WILLIAM KENT.—Is it the intention to have the actual inside diameter less than the nominal?

Mr. Wood. MR. WOOD.—There are probably one or two instances in which the thickness of the pipe and the standard outside diameter brings the internal diameter a trifle below the standard, but there is but one case in which it runs up to 0.1 inch with 4-inch pipe. It has been difficult to harmonize theoretical considerations and established practice. I think we succeeded very well in reducing the variation to only 0.1 inch.

On motion the specifications in the form proposed were referred to letter-ballot.*

*These specifications were adopted by letter-ballot on November 15, 1904.—ED.

PROPOSED STANDARD SPECIFICATIONS FOR LOCOMOTIVE CYLINDERS.

Process of Manufacture.

Locomotive cylinders shall be made from good quality of close-grained gray iron cast in a dry sand mold.

Chemical Properties.

Drillings taken from test pieces cast as hereafter mentioned shall conform to the following limits in chemical composition:

Silicon	from 1.25 to 1.75	per cent.
Phosphorus	not over .9	"
Sulphur	" .10	"

Physical Properties.

The minimum physical qualities for cylinder iron shall be as follows:

The "Arbitration Test Bar," $1\frac{1}{4}$ inches in diameter, with supports 12 inches apart, shall have a transverse strength not less than 2,700 pounds, centrally applied, and a deflection not less than 0.08 of an inch.*

Test Pieces and Method of Testing.

The standard test shall be $1\frac{1}{4}$ inches in diameter, about 14 inches long, cast on end in dry sand. The drillings for analysis shall be taken from this test piece, but in case of rejection the manufacturer shall have option of analyzing drillings from the bore of the cylinder, upon which analysis the acceptance or rejection of the cylinder shall be based.

One test piece for each cylinder shall be required.

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*In the amended specifications, adopted by letter-ballot on Nov. 15, 1904, the transverse strength is increased from 2,700 to 3,000 pounds, and the minimum deflection from 0.08 to 0.10 in. No other changes were made.—Ed.

CHARACTER OF CASTINGS.

Castings shall be smooth, well cleaned, free from blowholes, shrinkage cracks or other defects, and must finish to blue-print size.

Each cylinder shall have cast on each side of saddle manufacturer's mark, serial number, date made and mark showing order number.

INSPECTOR.

The Inspector representing the purchaser shall have all reasonable facilities afforded to him by the manufacturer to satisfy himself that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of the manufacturer.

DISCUSSION.

THE PRESIDENT.—Can any one inform us why a lower limit The President.
of 1.25 per cent. was adopted for silicon?

J. A. KINKEAD.—That limit was adopted because iron con- Mr. Kinkead.
taining less silicon, and therefore harder, is liable to fail in service by cracking. I think Mr. Diller has had experience with silicon running as low as 0.75 per cent. He was once connected with a foundry where low silicon caused a great deal of trouble and expense.

T. D. WEST.—At one time that firm had a great deal of Mr. West.
trouble with shrinkage, and also with cracking, and I was called in to see if I could help them, I found they were using iron very low in silicon. In some tests it was as low as 0.60 per cent., the sulphur as high as 0.15 per cent., both giving what I considered too hard an iron. However, I believe the specifications are a little too high in silicon, and will make the metal too soft for a good-wearing cylinder. Of course, this depends partly on the thickness, but nevertheless I think that the silicon should be lowered at least 25 points for the general run of cylinders.

MR. DILLER.—With that low-silicon iron we had about 0.07 Mr. Diller.
to 0.08 per cent. sulphur, and with higher silicon and higher sulphur, we got about the same results. When using higher sulphur iron, we tried for 1.25 per cent. silicon.

THE PRESIDENT.—Most of the cylinders cast at Altoona The President.
show about 1.50 per cent. of silicon. If we had made this specification, we would have placed the silicon at from 1.00 to 1.75 per cent.

WM. KENT.—Why was the limit for phosphorus placed at 0.9 Mr. Kent.
per cent.

MR. KINKEAD—Phosphorus is used by the foundryman to Mr. Kinkead.
control shrinkage to a great extent although the less phosphorus, the more strength. It was thought that 0.9 per cent. was about the right limit, the iron being too weak with higher phosphorus. There are many localities in which high phosphorus iron is about

Mr. Kinkead. all one can get. In Canada the irons run from 1.0 to 1.5 per cent. phosphorus and such iron is liable to be weak in transverse strength —not brittle, but weak. Cylinder walls average about 1½ inches thick, and if the phosphorus is high, the metal is too weak.

Mr. Moldenke. RICHARD MOLDENKE.—In regard to the "Arbitration Test Bar," knowing what is going on in the foundry world, I can say that there is no such thing as a test-bar in general use. Mr. Keep claims that the 1 inch square bar is. You will find it in some shops, and then again, you will find the 1 by 2 inch bar. Others have round bars of various diameters, and still some others a hexagon bar. I rather think we are American enough to stand on our feet, and when we know what is good to take, to take it, regardless of what might have been the leanings of others who were on ahead. The American tendency at the present time is to give the iron in the bars the best chance for uniformity of structure and casting conditions. We can thus at once eliminate a lot of sizes and shapes, and by combining the theoretically proper conditions with commercial requirements, we will arrive at just what the Committee did when adopting the "Arbitration Bar" as it is now proposed.

Mr. Kinkead. MR. KINKEAD.—Mr. Keep made a statement in a recent article in regard to this test-bar, exactly contrary to Mr. Moldenke. He called it an abortion cast-iron test, saying the gases which accumulate cannot get up through the iron resulting in blow holes in the bar. He defends a test-bar cast on the flat instead of on the end, as dirt in the iron will rise to the top of the bar and not particularly influence the transverse test.

Mr. Christie. JAMES CHRISTIE.—We have for many years required and obtained 0.15 inch deflection for a one inch square test-bar 12 inches between supports. For the metal under consideration I think 0.08 inch is too low, probably 0.12 inch would be low enough.

Mr. Kinkead. MR. KINKEAD.—I feel that I owe an apology. We drew up the specifications, and my own facilities for measuring deflections were rather crude. Since that time I have made quite a number of tests on this bar and find the deflections greater than called for by the specification.

Mr. Bunnell. F. O. BUNNELL.—In view of the remarks of Mr. Kinkead relative to the uncertainty connected with certain requirements of the specifications, I shall like to ask if it would not be well to

refer them back to the committee for further investigation with a view of getting these physical requirements on a more positive basis? Mr. Burrell.

The motion was made and carried that these specifications be referred back to the committee, and that the Executive Committee be empowered to submit the amended specifications to letter-ballot.*

*The amended specifications were adopted by letter-ballot November 15, 1904. The amendments are indicated in a foot-note, p. 69.—ED.

PROPOSED STANDARD SPECIFICATIONS FOR CAST-IRON CAR WHEELS.

The wheels furnished under this specification must be made from the best materials, and in accordance with the best foundry methods. The following pattern analysis is given for information, as representing the chemistry of a good cast-iron wheel. Successful wheels, varying in some of the constituents quite considerably from the figures given, may be made:

Total carbon	3.50 per cent.
Graphitic carbon	2.90 "
Combined carbon	0.60 "
Silicon	0.70 "
Manganese	0.40 "
Phosphorus	0.50 "
Sulphur	0.08 "

1. Wheels will be inspected and tested at the place of manufacture.

2. All wheels must conform in general design and in measurements to drawings, which will be furnished, and any departure from the standard drawing must be by special permission in writing, and manufacturers wishing to deviate from the standard dimensions must submit duplicate drawings showing the proposed changes, which must be approved.

3. The following table gives data as to weight and tests of various kinds of wheels for different kinds of cars and service:

Wheel		33-inch diameter Frgt. and Pass. cars			36-inch diameter.	
Kind of service		60,000 lbs. capacity and less.	70,000 lbs. capacity	100,000 lbs. capacity	Passenger Cars.	Locomotive Tenders.
Number		1	2	3	4	5
Weight	Maximum	590 lbs.	650 lbs.	720 lbs.	705 lbs.	760 lbs.
	Minimum	560 lbs.	610 lbs.	670 lbs.	680 lbs.	720 lbs.
Height of drop, ft.		12	12	12	12	12
Number of blows		10	12	15	12	15

4. Each wheel must have plainly cast on the outside plate the name of the maker and place of manufacture. Each wheel must also have cast on the inside double plate the date of casting and a serial foundry number. The manufacturer must also provide for the guarantee mark, if so required by the contract. No wheel bearing a duplicate number, or a number which has once been passed upon, will be considered. Numbers of wheels once rejected will remain unfilled. No wheel bearing an indistinct number or date, or any evidence of an altered or defaced number will be considered.

5. All wheels offered for inspection must have been measured with a standard tape measure and must have the shrinkage number stenciled in plain figures on the inside of the wheel. The standard tape measure must correspond in form and construction to the "Wheel Circumference Measure" established by the Master Car Builders' Association in 1900. The nomenclature of that measure need not, however, be followed, it being sufficient if the graduating marks indicating tape sizes are one-eighth of an inch apart. Any convenient method of showing the shrinkage or stencil number may be employed. Experience shows that standard tape measures elongate a little with use, and it is essential to have them frequently compared and rectified. When ready for inspection, the wheels must be arranged in rows according to shrinkage numbers, all wheels of the same date being grouped together. Wheels bearing dates more than thirty days prior to the date of inspection will not be accepted for test, except by permission. For any single inspection and test only wheels having three consecutive shrinkage or stencil numbers will be considered. The manufacturer will, of course, decide what three shrinkage or stencil numbers he will submit in any given lot of 103 wheels offered, and the same three shrinkage or stencil numbers need not be offered each time.

6. The body of the wheels must be smooth and free from slag and blowholes, and the hubs must be solid. Wheels will not be rejected because of drawing around the center core. The tread and throat of the wheels must be smooth, free from deep and irregular wrinkles, slag, sand wash, chill cracks or swollen rims, and be free from any evidence of hollow rims, and the throat and thread must be practically free from sweat.

7. Wheels tested must show soft, clean, gray iron, free from defects, such as holes containing slag or dirt more than one-quarter of an inch in diameter, or clusters of such holes, honeycombing of iron in the hub, white iron in the plates or hub, or clear white iron around the anchors of chaplets at a greater distance than one-half of an inch in any direction. The depth of the clear white iron must not exceed seven-eighths of an inch at the throat and one inch at the middle of the tread, nor must it be less than three-eighths of an inch at the throat or any part of the tread. The blending of the white iron with the gray iron behind must be without any distinct line of demarcation, and the iron must not have a mottled appearance in any part of the wheel at a greater distance than one and five-eighths inches from the tread or throat. The depth of chill will be determined by inspection of the three test wheels described below, all test wheels being broken for this purpose, if necessary. If one only of the three test wheels fails in limits of chill, all the lot under test of the same shrinkage or stencil number will be rejected and the test will be regarded as finished so far as this lot of 103 wheels is concerned. The manufacturer may, however, offer the wheels of the other two shrinkage or stencil numbers, provided they are acceptable in other respects as constituents of another 103 wheels for a subsequent test. If two of the three test wheels fail in limits of chill, the wheels in the lot of 103 of the same shrinkage or stencil number as these two wheels will be rejected, and, as before, the test will be regarded as finished so far as this lot of 103 wheels is concerned. The manufacturer may, however, offer the wheels of the third shrinkage or stencil number, provided they are acceptable in other respects, as constituents of another 103 wheels for a subsequent test. If all three test wheels fail in limits of chill, of course the whole hundred will be rejected.

8. The manufacturer must notify when he is ready to ship not less than 100 wheels; must await the arrival of the Inspector; must have a car, or cars, ready to be loaded with the wheels, and must furnish facilities and labor to enable the Inspector to inspect, test, load and ship the wheels promptly. Wheels offered for inspection must not be covered with any substance which will hide defects.

9. A hundred or more wheels being ready for test, the Inspec-

tor will make a list of the wheel numbers, at the same time examining each wheel for defects. Any wheels which fail to conform to specifications by reason of defects must be laid aside, and such wheels will not be accepted for shipment. As individual wheels are rejected, others of the proper shrinkage, or stencil number, may be offered to keep the number good.

10. The Inspector will retape not less than 10 per cent of the wheels offered for test, and if he finds any showing wrong tape-marking, he will tape the whole lot and require them to be restenciled, at the same time having the old stencil marks obliterated. He will weigh and make check measurements of at least 10 per cent of the wheels offered for test, and if any of these wheels fail to conform to the specification, he will weigh and measure the whole lot, refusing to accept for shipment any wheels which fail in these respects.

11. Experience indicates that wheels with higher shrinkage or lower stencil numbers are more apt to fail on thermal test; more apt to fail on drop test, and more apt to exceed the maximum allowable chill than those with higher stencil or lower shrinkage numbers; while, on the other hand, wheels with higher stencil or lower shrinkage numbers are more apt to be deficient in chill. For each 103 wheels apparently acceptable, the Inspector will select three wheels for test—one from each of the three shrinkage or stencil numbers offered. One of these wheels chosen for this purpose by the Inspector must be tested by drop test as follows: The wheel must be placed flange downward in an anvil block weighing not less than 1,700 pounds, set on rubble masonry two feet deep and having three supports not more than five inches wide for the flange of the wheel to rest on. It must be struck centrally upon the hub by a weight of 140 pounds, falling from a height as shown in the table on page 16. The end of the falling weight must be flat, so as to strike fairly on the hub, and when by wear the bottom of the weight assumes a round or conical form, it must be replaced. The machine for making this test is shown on drawings which will be furnished. Should the wheels stands without breaking in two or more pieces, the number of blow, shown in the above table, the one hundred wheels represented by it will be considered satisfactory as to this test. Should it fail, the whole hundred will be rejected.

12. The other two test wheels must be tested as follows: The wheels must be laid flange down in the sand, and a channelway one and one-half inches in width at the center of the tread and four inches deep must be molded with green sand around the wheel. The clean tread of the wheel must form one side of this channelway, and the clean flange must form as much of the bottom as its width will cover. The channelway must then be filled to the top from one ladle with molten cast iron, which must be poured directly into the channelway without previous cooling or stirring, and this iron must be so hot, when poured, that the ring which is formed when the metal is cold shall be solid or free from wrinkles or layers. Iron at this temperature will usually cut a hole at the point of impact with the flange. In order to avoid spitting during the pouring, the tread and inside of the flange during the thermal test should be covered with a coat of shellac; wheels which are wet or which have been exposed to snow or frost may be warmed sufficiently to dry them or remove the frost before testing, but under no circumstances must the thermal test be applied to a wheel that in any part feels warm to the hand. The time when pouring ceases must be noted, and two minutes later an examination of the wheel under test must be made. If the wheel is found broken in pieces, or if any crack in the plates extends through or into the tread, the test wheel will be regarded as having failed. If both wheels stand, the whole hundred will be accepted as to this test. If both fail, the whole hundred will be rejected. If one only of the thermal test wheels fails, all of the lot under test of the same shrinkage or stencil number will be rejected, and the test will be regarded as finished, so far as this lot of wheels is concerned. The manufacturer may, however, offer the wheels of the other two shrinkage or stencil numbers, provided they are acceptable in other respects, as constituents of another 103 wheels for a subsequent test.

13. All wheels which pass inspection and test will be regarded as accepted, and may be either shipped or stored for future shipment, as arranged. It is desired that shipments should be, as far as possible, in lots of 100 wheels. In all cases the Inspector must witness the shipment, and he must give, in his report, the numbers of all wheels inspected and the disposition made of them.

14. Individual wheels will be considered to have failed and will not be accepted or further considered, which,

First. Do not conform to standard design and measurement.

Second. Are under or over weight.

Third. Have the physical defects described in Section 6.

15. Each 103 wheels submitted for test will be considered to have failed and will not be accepted or considered further, if,

First. The test wheels do not conform to Section 7, especially as to limits of white iron in the throat and tread and around chaplets.

Second. One of the test wheels does not stand the drop test as described in Section 11.

Third. Both of the two test wheels do not stand the thermal test as described in Section 12.

DISCUSSION.

The President. THE PRESIDENT.—I may say that when these specifications were discussed at the recent meeting of the American Institute of Mining Engineers, as Chairman of the sub-committee by whom these specifications were prepared, I offered an explanatory statement as follows:

It is evident that, as the size and weight of cars have increased, the demands on the cast-iron car-wheel have become more and more severe. Fortunately, the factor of safety in the cast-iron wheel as originally made was so large, that it is only as the sizes of freight-cars began to reach a capacity of from 80,000 to 100,000 lbs. that the question of wheels began to give some anxiety. A moment's thought will show that, as freight- and passenger-cars have increased in weight and size, much more severe duty is required of the same eight wheels than was formerly the case; in other words, although the cars have increased from a capacity of 15 tons to 50 tons each, the number of wheels under a car has not been increased, at least to any general extent. It is true, some cars have been equipped with 12 wheels, but this is not the rule.

As is stated above, the duty which the wheel must perform has become much more severe, and although the wheel was clearly able to stand some increase, it is evident there must be a limit somewhere which cannot be exceeded. Meanwhile, it is the part of wisdom to make better wheels, if possible, and accordingly no little study is now being devoted to the requirements for cast-iron car-wheels, and modifications are being made both in increasing the weight of the wheel and in improving the quality of the metal of which it is made.

This desire to improve the quality of the wheel has led to the preparation of specifications for its manufacture, and within the last 15 years a more rigid scrutiny of the wheel is characteristic of the purchaser, with a corresponding effort on the part of the manufacturer to meet the special requirements.

The specifications for cast-iron car-wheels, submitted by a sub-committee of the American Society for Testing Materials, is believed to embody the best information so far as is known on the subject, although of course there are some differences of opinion upon various points. The section in the specifications devoted to the chemical composition of the cast-iron is given simply for guidance rather than for any special requirement.

Sections I and II are self-explanatory.

The President

Section III gives the proposed weights of wheels for various services, a question concerning which there is a considerable difference of opinion. The manufacturers in general prefer a heavier wheel than those given in the specifications. It is obvious that the smaller the weight, the better must be the quality of the metal in order to stand the same strain; and it is natural, in view of the uncertainties of wheel manufacture, that makers should desire to increase the weight as much as possible, for the reason that metal not quite as good, if there is more of it and it is properly disposed, will give the requisite strength.

Section IV needs no special remark.

Section V is devoted to the subject of tape-sizes. No foundry is able to make its total output all of the same circumferential size, and experience has shown that there is an intimate relation in any good foundry between satisfactory wheels and tape-sizes.

There are several reasons why the output of a foundry varies in diameter or circumferential measurement. First, although the molds are supposed to be of the same size originally, as a matter of fact they are not. Moreover, a mold which has been used a number of times is apt to have been increased a little in diameter, as well as to have become worn a little. This cause for variation in tape-sizes is not a very serious matter, because efforts are usually made to keep the molds fairly uniform in size.

Another cause for variation in size, is the temperature of pouring the metal; and it will be readily understood that greater shrinkage is characteri tic of metal cast at higher temperatures. Furthermore, a difference in chemical composition makes a difference in the shrinkage. However, the most important cause for variation in tape-size is the effect of the annealing. It is well known that as fast as the wheels are taken out of molds while they are still red-hot, they are put in annealing-pits containing 15 wheels or more. The annealing-pits are constructed of metal tubes lined with fire brick, the interstices between the pits being filled with sand, the whole being arranged in order to allow the wheel to cool slowly. Generally the wheels remain in the pits for four days, during which time certain changes take place in the metal, and in most cases the tape-size of the wheel is increased. Experiment has indicated that a re-annealing, that is, putting a wheel into the pit a second time between a number of freshly-cast hot wheels, will at times increase the tape-size two numbers. Furthermore, the wheels at the top and bottom of the pit do not increase in size in the same proportion as do those in the middle of the pit.

It is perhaps not necessary at this time to go into the changes which take place in the annealing-pit, farther than to say that those wheels which come out of the pit nearest to the size which they had when put into the pit, or in other words, those wheels which are less annealed, are found by experience to be most likely to fail on the drop-test, and are less likely to stand the thermal-test also. It will be seen, therefore, that there is a very intimate relation between tape-sizes and successful output,

The President. which explains why so much reliance is placed on the tape-sizes. The wheel-circumference measure used by the Master Car Builders' Association is a brass tape about an inch wide, having supports at different points, so that the wheel may be measured on the tread at the same distance from the flange.

There is a discrepancy in the wheel-making business, as to the manner in which tape-sizes shall be specified. The Master Car Builders' Association has a nomenclature of "o" for a standard-size wheel, plus 1, 2 and 3, for wheels larger than the standard, and minus 1, 2, 3, for those smaller than the standard. Some works have an arbitrary nomenclature,—for instance, the Altoona wheel-foundry standard size is 120, but wheels of 119, 121, 122, 123, etc., are put in service. As stated in Section V, the nomenclature is immaterial, it being essential only that the different sizes shall differ from each other by one-eighth inch.

The object of the clause, which requires that wheels not more than 30 days old shall be submitted for the test, is that the date of the guarantee is taken from the date cast in the wheel, and if wheels remain two or three months before test, an unfair date of the guarantee is taken.

The reason for considering only three sizes at one time will be discussed later in this paper.

Section VI, referring especially to the physical appearance, will be readily understood by any one familiar with foundry-work in manufacturing wheels.

Section VII deals with the chill. It is well known that a cast-iron car-wheel is practically a gray-iron wheel having a tire, if it may be so called, of chilled iron. The chilled iron of the tire is brittle, extremely hard, and of not much value so far as strength is concerned. It is the gray iron that is relied upon for strength. Of course it is understood that the chilled iron is a part of the casting, the chill being formed by having that part of the mold, which is to produce the chill, made of metal, the rest of the mold being made of sand. In casting the wheels, if the iron is of the proper chemical composition, that part of it which touches the iron of the mold is instantly cooled and becomes white chilled iron, while the part which touches the sand in the mold becomes gray iron. As already explained the tape-size is an important element in the wheel, and in addition to strength and ability to stand the thermal-test, the chill likewise is a function of the tape-size. The lowest tape-size in any foundry will be apt to have the highest chill, and may fail on test from having too much chill, while the higher tape-sizes, which mean the greater circumference, have the least chill and may fail from having too little chill.

The requirements of Section VII referring to rejections are not based on wide experience. It was formerly the custom to reject an entire lot of 100 wheels, if any of the test-wheels failed from any cause. This custom was considered a hardship by the manufacturers, and in view of the intimate relation between tape-sizes and successful wheels, there has been introduced into these specifications, the authority to reject out of each 100 wheels tested only the other wheels of the same tape-size as the

wheel which failed, thus allowing the other tape-sizes to come up again. The President.
This has not been tried so far as is known, but those who have had most experience in wheel-manufacture and have done most work in testing the wheels see no reason why any greater risks should be incurred by the users in following this plan, than with the old plan of rejecting all of the hundred wheels for failure to stand test; at the same time it enables the manufacturers to produce a greater proportion of successful wheels.

Sections VIII, IX and X are self-explanatory, and need no special remarks.

Section XI concerns the drop-test. It will be noted that what has been said about tape-sizes permeates the whole specification, and that this is especially true with regard ts the drop-test and the thermal-test. As the specification is now drawn, each tape-size gets a test, either a drop or a thermal one. It was formerly the custom to allow four, five or possibly six tape-sizes in a hundred wheels, and to allow the inspector to choose the wheels for test arbitrarily. It is believed that the testing of each tape-size is a decided step forward in this matter; and if this practice is followed, not only will there be greater certainty of getting good wheels, but also, as the specification is drawn, less hardship will be put upon the manufacturer.

It will be observed that only one of the three wheels is subjected to the drop-test. There is a large difference of opinion among wheel-makers and consumers concerning the real value of the drop-test. Many consumers do not hesitate to say that they think the drop-test is of very little value, since it is so easy to strengthen the wheel at those points where experience has shown them to fail under the drop-test, and with any kind of metal, wheels can be made which will stand it. A very slight thickening of the plates without any change in the quality of the metal, together with a slight diminution in thickness at other points where the wheel has never failed, so as not to exceed maximum weights, will enable a foundry to turn out wheels that will stand the drop-test. However, there are believed to be some advantages gained by testing under the drop, and many consumers have been unwilling to abolish this test entirely. Those who do not place much stress on the drop-test, rely almost wholly on the thermal-test, and think that everything that is covered by the drop-test can likewise be obtained equally as well, or better, by the thermal-test. But car-wheels in actual service do receive considerable shocks, and it is some satisfaction to know that the wheels will stand them without breaking; accordingly, it seems probable that the drop-test will maintain a place in the specifications for some time to come.

It has been suggested that the proposed drop-test is not severe enough and that the weight of trip or the height should be increased. It is to be confessed we think that in view of the increase in weight which has characterized the past few years there is much force in this suggestion.

Section XII is devoted to the thermal-test, which is believed to be by far the most important test in the specifications, and the one which tells the most about the wheels. The origin of the thermal-test may be

The President. not uninteresting. Until recently the principal portion of the failures of cast-iron wheels were found to occur at the end of, or some little distance beyond, a long-continued application of the brakes, as, for example, in going down a long grade. This effect naturally led to a study of the reasons why bursted, cracked or broken wheels under cars should occur at these points. A little reasoning on the matter, together with an investigation of the wheels after they had reached the bottom of the grade, soon showed that the application of the brakes resulted in a heating of the outside circumference of the wheel. Strangely enough, it was possible to find in a wheel under a car which had had the brakes applied down a long grade, that the rim or outer portion of the wheel was frequently hot enough to burn the fingers, while toward the hub it was apparently absolutely cold. In other words, the heat generated by the friction of the brake did not transmit itself throughout the whole wheel uniformly, until considerable time had elapsed. It not infrequently takes half an hour for a train to run down a long grade, and during this time, the metal six inches away from the rim of the wheel is quite cold to the hand, while the rim itself is quite hot. The heating of the rim of course produces expansion; and this causes a good deal of strain between the metal at the rim and that at the center of the wheel, which results, not infrequently, in the bursting or the failure of the wheel in service. The thermal-test is designed to similate conditions of a long-continued application of the brake. It will be seen from the descriptive matter in Section XII that the rim of the wheel is highly heated by the molten cast-iron poured against it, while the center is not heated, giving exactly the conditions produced by long-continued application of the brakes, perhaps more severe than would ever occur in service.

During the development of the thermal-test many wheels of various makes were tested; some burst within a few seconds after the pouring of the hot metal was finished, so much so that, at times, the molten metal was spattered around by the bursting. Some stood for a longer period of time, while others stood until the molten metal had become black-hot, or even cooled down to ordinary temperatures. It was also found that the wheels cracked in eight different ways. Some of these breaks or cracks, such, for instance, as the breaking of the brackets, were considered harmless, and accordingly only two of the eight different fractures were chosen to embody in the test, namely, breaking in pieces, and cracks involving the tread.

As already mentioned, the length of time from the cessation of pouring until the cracks appeared was found to vary from a few seconds to about seven minutes, and in order to make the specification workable, a period of two minutes was chosen as the time through which the wheel must be tested. It is believed that no test for cast-iron wheels has been suggested that is so important, or that tells so much, or that has done so much to improve their quality, as the thermal-test.

There is a difference of opinion concerning the severity of the test. Some think that an inch of molten metal in the channel-way is enough,

others, that a shorter time-limit should be required. It is evident that, by varying either the thickness of the molten metal, or the length of time, the test may be made more or less severe. Also another factor might be introduced, namely, that no cracks of any kind should be formed, so that the test taken as a whole has within itself very great possibilities. I have seen many wheels that did not break in any place during the thermal-test, yet the percentage is small. The same characteristic in regard to allowing tape-sizes which have not failed, to appear again, applies in Section XII to the thermal-tests. The President.

Sections XIII, XIV and XV do not require any special comment.

Some query may arise, as to why, if the test-wheel representing any tape-size passes any one of the tests, such as chill- or thermal-test, these wheels should not be accepted, as to the test which they pass successfully, and not be required to stand test again as a constituent of a new lot of 103 wheels, as the specifications require. At first sight this seems unduly severe, but it should be remembered that wheels are usually bought in large numbers, that a hundred wheels make a car-load and consequently this number is a convenient unit to be considered, and that at some of the smaller wheel-foundries (and indeed at some of the larger ones), when the demand for wheels is pressing, often only a hundred wheels are ready for test at one time. If, now, the lot fails from any cause, the inspector must leave this foundry, and wait until another lot is ready. It was felt, therefore, that to require the inspector to keep track of partial tests would unduly complicate the inspection, and throw doubt on its value. Moreover, as has already been stated, previous specifications have usually rejected the whole hundred wheels, if any one of the three test-wheels failed, on any of the tests; while the present specifications reject absolutely only those wheels of the same tape-size, as the test-wheel which fails, allowing the other tape-sizes to appear for test again, which is as great a modification as in the present state of the wheel-problem, it seems wise to make. Furthermore, it should not be forgotten that the prime object of the specifications is to get as great certainty as possible, that only safe wheels shall go into the service, and doubtful ones shall not pass. Finally, since the consumer pays for the test-wheels in the price which is agreed upon, it was felt that no serious hardship is introduced by the specification as drawn, and that it is better to err, if at all, on the side of safety.

Taken as a whole, it is perhaps safe to say that, for ordinary service (by which is meant for all service except under 40- and 50-ton freight-cars) the wheels which pass the tests of these specifications will be safe and will give fairly good results. There are some points in connection with the failure of wheels under heavy cars, that need further study; and it is more than probable that, as this study progresses, it may be found essential to change, or modify, some of the requirements of the specifications. The special failure of wheels under heavy cars is a circumferential crack either in the tread or in the throat of the wheel, resulting sometimes in the breaking-off of the flange. The causes leading up to this failure

The President. are complicated, and it is possible that modifications in the design of the cars themselves may very greatly diminish the number of failures of this kind. On the other hand, a most earnest study of the wheel itself is now being made, in order to enable it to resist successfully the strains producing these circumferential cracks. It is fair to say that there are some who believe that steel-tired wheels or some kind of a steel wheel will be necessary for heavy service. There are also some who are strongly of the opinion that a cast-iron wheel can be made which will successfully meet the conditions under heavy cars, and will thus perpetuate the remarkable and wonderful reputation which the cast-iron wheel has made for itself in this country.

Mr. Sherman. C. W. SHERMAN.—About four-fifths of the consumers now use 600 or 700-pound wheels, with variations of 2 per cent. in weight from the mean specifications. The 600-pound wheel applies to the 60,000-pound capacity car, and I think it would be desirable to change the weight specification to agree with that ordered by the majority of users.

The President. THE PRESIDENT.—In deciding on weights, the principal feeling has been that assuming that the wheel is properly designed, the better the metal, the lighter the wheel can be made, so that the weight in a sense, is a check on the quality of the metal.

It will be noted that great weight is laid on the question of tape sizes. The tape, as is well known, is a brass strip about an inch broad with supports on it, so that the circumference will be measured at certain equal distances from the flange. The method of graduating tape sizes is not uniform. The Master Car Builders' tape has a nomenclature of zero for a 33-inch wheel, and then they go three numbers each way, plus 1, 2 and 3, and minus 1, 2 and 3, for other sizes. The variation between sizes is one-eighth inch. At Altoona the nomenclature for a 38-inch wheel is 120, and wheels are put into service having tape sizes of 119, 122 and 123. The specifications do not insist on any special nomenclature, but simply that the tape size shall differ from each other by $\frac{1}{8}$ inch. As to the importance of tape sizes, it is well known by those interested in wheel making, that the tape size of a wheel, tells a good deal about it. Theoretically wheels as they come from the mold, have the same size, but as a matter of fact they do not. First, the molds are not turned up to exactly the same size, second, they wear a little in service, and third, the temperature of pouring influencing the shrinkage, makes a difference; but more important

than all, is the influence of the annealing pit. Twenty wheels put in the annealing pit of exactly the same size when put in, would come out probably with twenty different tape sizes. You are familiar with the facts brought out by Mr. Outerbridge upon the growth of cast iron under the influence of heat. This applies exactly in car wheel manufacture. To such an extent is this true, that it is easy to increase the size of a wheel by one or two numbers, by a second annealing. Now in the specifications the tape sizes are made the basis of the whole thing. The manufacturer only offers in each hundred wheels, three tape sizes, and it is well known that the smaller the tape size obtained from any given mold, the deeper the chill, the more brittle the metal, and the less likely it will be to stand the drop and thermal tests. On the other hand, the larger the tape size from any given mold, the less the chill and stronger the wheel usually. The President.

MR. SHERMAN.—I think the idea of testing wheels with the tape sizes is a very good one and one that should be embodied in the specifications. All railroad specifications now require the wheels to be chosen at random, but as a matter of fact the inspector goes through the entire pile and picks out the extreme tape sizes both high and low, the high for strength and the low for chill. It is assumed that the intermediate sizes are better than the ones tested, and as it is the best indication the consumer has as to the quality of the product, the fact should be embodied in the specifications. Mr. Sherman

There is one point about the specifications, that of limiting the tape sizes to three in any one inspection. I hardly think it would be worth much in practice because wheel makers receive a great many orders from large railroads, who allow from four and sometimes five sizes, to be used and it would possibly be necessary to change that to allow us to offer one test from each extreme tape size. If that wheel should fail all wheels of the same tape size should be rejected and the next size chosen for test. If the wheels pass inspection the tape sizes tested and all intervening sizes should be accepted.

J. C. RAMAGE.—It has been our practice, and I presume that of other roads, not to select test wheels at random, but having in mind the value of the tape number as a general indication of the character of a wheel, to select for both drop and thermal test, Mr. Ramage

Mr. Ramage. wheels of the highest shrinkage number included in the lot of wheels offered. We occasionally vary this practice by taking for drop test a wheel of the lowest shrinkage, as this enables us to also guard against the wheels having too light a chill.

In reading the proposed specifications, it occurs to me that instead of selecting one wheel of each shrinkage number for test, that it would be more consistent with the theory on which the specifications are based, to select the test wheels from the extreme tape numbers included in the lot of wheels offered, disregarding the intermediate tape number.

The President THE PRESIDENT.—It may perhaps be reasonably mentioned, that there is a growing feeling among the users of cast iron wheels, that they are not prepared to take risks and use wheels which are inferior from any cause. With the increase in weight of equipment and in speeds, the cast iron wheels is really being called upon to show its right to a continued existence, and not a few consumers think that the limit of the usefulness of the cast iron wheel has been reached.

Mr. Ramage. MR. RAMAGE.—While the tape size is a general indication of the chill and hardness of a wheel, I think it every inspector's experience that you cannot arbitrarily depend upon a tape, one wheel always having more chill than a tape two wheel.

Mr. Lemen. W. W. LEMEN.—We have been very successful in the testing department of the Norfolk and Western Railroad in choosing wheels from tape sizes. We were successful in showing the manufacturers by the tape alone, that a large percentage of a recent shipment of wheels were not proper for service, and we feel that the allowance of three points is all right. If my inspector should report variations in the wheels running more than three points, I should be rather afraid to accept them.

We use ordinarily low-chilled wheels for the drop test and high-chilled wheels for thermal tests. There are some other features that enter into the choosing of wheels which our specifications do not bring out, but which enable us from experience to discriminate between good and bad wheels, as, for example, their location in the annealing pit. The top wheel invariably fails; it is never a good hard wheel that will meet the thermal test. We have experimented for some time with the use of heavy asbestos for covering, but we always get bad top wheels.

Mr. Sherman.—It is the common practice among wheel-makers to make about four tape sizes a day, which are produced from the same mixture owing to variations in melting iron, size of chillers, and minor influences too numerous to mention. Mr. Sherman.

The President.—The only real assumption made in the specifications is that each wheel which has a given tape size, is as good as each other wheel which has that tape size. On the other hand, by the old method of testing, either of a day's work, or selecting five or more numbers, and taking one of the highest and one of the lowest tape sizes for test, many more uncertainties and assumptions were introduced. Moreover, considering only three sizes in each hundred wheels, does not impose any hardship on the manufacturer, as it seems to us, since if the test wheel of either tape size fails, only those wheels of the same size in the hundred are rejected. Moreover the specification protects the consumer, since each tape size is tested, and the only assumption made is as already stated, that all wheels of the same tape size, are equally good. The President.

Mr. Ramage.—The only assumption is that all wheels of the same tape number are the same. Could not this assumption be strengthened by limiting the number of casting dates that would be allowed to go to make up the one hundred wheels? Personally I have always preferred to inspect wheels by casting dates because the character of the charge is not so apt to radically change during a day, as it is from day to day. It seems to me, therefore, to be desirable and practicable to limit the number of casting dates going to make up a lot of one hundred wheels. Most foundries are able to offer one hundred wheels from a single day's work; some of the smaller ones could not do so, but any foundry could probably make up the one hundred wheels from two or, at the most, three day's work. Mr. Ramage.

The President.—The plan Mr. Ramage suggests would lead to a good deal of complication. It was thought best to rest on this bare assumption, that wheels of the same tape size are equally good wheels. The President.

F. O. Bunnell.—I should like to ask the President whether his experience warrants the conclusion that if wheels, irrespective of the tape sizes, stand the three tests specified, that they are perfectly safe to go into commission? Mr. Bunnell.

The President. THE PRESIDENT.—Our experience seems to justify this statement, that if the wheels stand the tests enumerated in these specifications, we are justified in putting them under cars.

Mr. Bunnell. MR. BUNNELL.—As I understand the specifications there is no one clause that covers the whole aspect of the case, and protection can only be gained through a series of clauses covering the different propositions. I should prefer to have a limit to the tape numbers as a measure of further protection, and one which I do not think would create friction with the manufacturers.

Mr. Sherman. MR. SHERMAN.—As to limiting the tape numbers, I think it might be easily covered in the specifications, so far as the difference in chiller is concerned.

One manufacturer's chillers ought to be all alike; possibly they are not like anothers, but there is no excuse for their not being uniform in each shop. We all know that the intermittent heating and cooling will cause the chiller to increase in diameter, etc., but I believe the great variations in the tape sizes is caused by variations in the melting and in the mixtures used. So far as testing the wheels by dates, I think it is quite common practice among makers to change their mixture during a heat, so that one part of a heat may not be the same as another part. While it is the practice to watch the dates very closely, it is not an absolute test; that is, if one wheel in a day's work stands you are not sure all the rest will stand.

Mr. Bunnell. MR. BUNNELL.—In inspecting wheels according to dates, while it is not an absolute test, and it is not certain that you are going to get uniformity, still it is more satisfactory to know that the wheels have been recently made. In a recent inspection I had difficulty with a manufacturer over the matter of including a lot of wheels which had been stored in the weather for a year or more. It seems to me that it would be well to limit the number of test lots in these hundred wheels to three or five days. That would give a reasonable degree of protection without inconvenience.

The President. THE PRESIDENT.—Among the suggestions made is one to increase the weight. Increase in weight of course has its principal bearing on ability to stand the drop test. It may be worth while to say that when the drop test was first established, very few wheels would stand even three blows, but it was quickly found that by strengthening the wheel at the points where it usually broke, by

using a little more metal, it was easy to make a wheel which would stand any drop test, and accordingly many consumers think that a drop test is of no value, since it is so easy, and with any kind of metal by using a little more of it at the proper point, to make a wheel which will stand almost any prescribed test. However, few railroad officers we fancy, will be willing to abolish the drop test for some time to come. The President.

Mr. Sherman.—I think the Master Car Builders are to adopt a 200-pound ball for the heavier wheels, but I believe that it is too heavy for a 600-pound wheel. It occurs to me that we should make the height the same for all classes of wheels, say 12 feet, and then increase the weight of the drop from a 140- or 150-pound ball for a 600- to a 175-pound ball for a 650-pound wheel, and a 200-pound ball for a 700-pound wheel. It is of course well-known that a 140-pound ball on a 700-pound wheel is practically no test at all. Mr. Sherman.

The President.—Would it not be better to increase the height of drop instead of increasing the weight of ball? The President.

Mr. Sherman.—I think it would be a great deal easier for the average foundryman to increase the weight of the drop than to increase the height of the testing machines, and the same result is accomplished. Mr. Sherman.

The President.—The thermal test is clearly the most important of the tests applied to wheels. It was noticed many years ago, that most wheels that cracked or burst in service, did so at the foot of long grades, and an examination indicated that the rim and tread of the wheel, were usually hot at the foot of the grade, while the metal between the rim and tread and the hub, was cold. It was obvious, therefore, that the application of the brakes produced a tendency for the wheel to expand at the tread. The thermal test produces the same results in the wheel as the brakes, namely, by heating the tread with the hot metal, expansion is produced, which after the metal is poured, results in bursting the wheel. Before the thermal test was established over 200 wheels were tested at Altoona, and these were found to break in eight different ways. Two of these breaks, namely, breaking in pieces, and the break involving the tread, were believed to be very dangerous. Moreover, the length of time that a wheel will stand the thermal test is an element in the problem. Some wheels crack in The President.

The President. a few seconds, some crack within a minute, and some will stand until the metal gets black hot, about seven minutes. Accordingly, two points were chosen to embody in the specifications, namely, the break must not involve the tread, and the time must be two minutes. We have great confidence in the thermal test.

Mr. Wood. WALTER WOOD.—What has been your experience in regard to re-annealed wheels?

The President. THE PRESIDENT.—Our experience is that re-annealed wheels usually stand the thermal test. It is believed, however, that re-annealed wheels do not wear as well. This point has not, so far as we know, been demonstrated. The action of the annealing pit is two-fold, first to relieve initial cooling strains, and second, to change the condition of the combined carbon. When the wheel is first cast, the combined carbon of the gray iron is about 1.25 per cent. In an annealed wheel the combined carbon is many times not over 0.50 per cent., and sometimes very much lower.

Mr. Sherman. MR. SHERMAN.—I should like to say a word about annealing wheels. The statement has been made that the top wheels in the annealing pit will not stand the test. It is our practice to use a cast-iron cover, and on top of the cast-iron cover is a covering of about 6 inches of hot sand. We have tested a very large number of wheels from the top of the pits, and invariably find they would stand a very good test. They will not stand as well as wheels further down, but they stand a good test.

One very large railroad is now buying wheels on thermal test, which specifies 2 minutes for 600-pound, 2½ minutes for 650-pound and 3 minutes for 700-pound wheels, without cracking through the tread. In view of all the trouble the railroads have been having with cast-iron wheels, I should be glad to see this specification adopted. The manufacturers can meet it if they use proper material, and I think it would be to the interest of the cast-iron wheel business to make the specifications more rigid on heavier wheels, allowing the test on the lighter weight wheels for 60,000-pound-capacity cars to remain as it is.

Mr. Ramage. MR. RAMAGE.—Is it the sense of the committee that it would be too severe to require that a wheel must not crack at all in the thermal test? A large percentage of the wheels we are offered stand two minutes or more without cracking at all, and I am therefore inclined to think that such a requirement would not be unrea-

sonable. Where a wheel does crack, it is evidence that it is weaker in some way than its mate. Since the matter of safe wheels is one of such vital importance, why not require all wheels to conform to the higher standard? Mr. Ramage.

MR. SHERMAN.—In my opinion it is too severe a test for a cast-iron wheel to demand that it shall not crack under the thermal test. I firmly believe that a wheel that does not crack through the rim is sufficiently strong to carry the load. Mr. Sherman.

E. MCLEAN.—Experience seems to show that the thermal test in its present shape, if rigidly enforced, is sufficiently severe to entirely eliminate unreliable wheels; this is quite conclusively proven by the fact that the Pennsylvania Railroad has in service east of Pittsburg and Erie some 30,000 steel cars of 100,000 pounds capacity, representing 240,000 wheels, a very large number of which have been in service over four years. These wheels were all purchased under specifications including the thermal test and up to the present time only three wheels in the entire lot have squarely broken down; that is, only three wheels have broken into two or more pieces from expansion due to long and severe application of brakes, and only four have cracked in the plates without the pieces breaking off. Of course, there has been quite a large number of broken flanges, primarily due in a great majority of cases to seams located at the throat or fillet, these seams invariably extending to the depth of the chill, but owing to its crystalline formation this tendency to check or seam at the throat is unquestionably a characteristic of white iron developed by some peculiar service conditions, and we do not believe that any test or specification can be devised that will eliminate the trouble. With regard to patterns, our experience shows that wheels made from all patterns will readily crack from expansion unless they are composed of good material. Changing the shape of the pattern will not eliminate the tendency to crack, but only change its location unless good elastic metal is used; if this is done, almost any shape of pattern will give satisfactory results. Mr. McLean.

MR. LEMEN.—I should like to ask whether it has been possible to determine by the thermal test what brings about the characteristic blue crack in the throat of the wheel when the flange breaks off. We find that a large percentage of accidents due to broken wheels are due to the flanges breaking off, and in almost Mr. Lemen.

Mr. Lemen. every instance we find that characteristic blue crack which often does not extend to the surface of the throat.

Mr. Sherman. MR. SHERMAN.—That is a question that is bothering every wheel-maker in the United States at the present time. We perhaps know that the design is faulty and the flange of a wheel will be greatly strengthened by using a three-quarter-inch throat radius and a flange one inch high, and when railroads adopt this flange, with an increased test for strength, I look for the trouble to stop.

The President. THE PRESIDENT.—It may not perhaps be unwise to say that there is very little difficulty at present with burst wheels, such as the thermal test and other tests in the specifications are supposed to guard against. The greatest difficulty at present with car wheels, is a circumferential crack in the tread which may extend one-quarter or one-third of the way around the wheel, and ultimately results in the flange coming off. The cause of the circumferential crack is not entirely evident, nor do we know at present any test to be applied to new wheels, which will insure against this circumferential crack. It is believed that the center plate, and the side bearings, have a very important influence on this circumferential crack. It is known that those cars which have the best center plates and the best side bearings, so that the trucks curve properly when they strike a curve, have less of these circumferential cracks. Possibly the wheel is not at fault.

The motion was made and carried that the specifications be referred back to the committee for further study, with instructions to report their conclusions at the next annual meeting.

PROPOSED STANDARD SPECIFICATIONS FOR MALLEABLE CASTINGS.

Process of Manufacture.

Malleable iron castings may be made by the open hearth, air furnace or cupola process. Cupola iron, however, is not recommended for heavy nor for important castings.

Chemical Properties.

Castings for which physical requirements are specified shall not contain over .06 sulphur nor over .225 phosphorus.

Physical Properties.

(1) *Standard Test Bar.* This bar shall be 1 inch square and 14 inches long, without chills and with ends left perfectly free in the mold. Three shall be cast in one mold, heavy risers insuring sound bars. Where the full heat goes into castings which are subject to specification, one mold shall be poured two minutes after tapping into the first ladle, and another mold from the last iron of the heat. Molds shall be suitably stamped to insure identification of the bars, the bars being annealed with the castings. Where only a partial heat is required for the work in hand, one mold should be cast from the first ladle used and another after the required iron has been tapped.

(2) Of the three test bars from the two molds required for each heat, one shall be tested for tensile strength and elongation, the other for transverse strength and deflection. The other remaining bar is reserved for either the transverse or tensile test, in case of the failure of the two other bars to come up to requirements. The halves of the bars broken transversely may also be used for tensile strength.

(3) Failure to reach the required limit for the tensile strength with elongation, as also the transverse strength with deflection, on the part of at least one test rejects the castings from that heat.

(4) *Tensile Test.* The tensile strength of a standard test bar for castings under specification shall not be less than 40,000 pounds* per square inch. The elongation measured in 2 inches shall not be less than $2\frac{1}{2}$ per cent.

(5) *Transverse Test.* The transverse strength of a standard test bar, on supports 12 inches apart, pressure being applied at center, shall not be less than 3,000 pounds, deflection being at least $\frac{1}{2}$ of an inch.

TEST LUGS.

Castings of special design or of special importance may be provided with suitable test lugs at the option of the inspector. At least one of these lugs shall be left on the casting for his inspection upon his request therefor.

ANNEALING.

(1) Malleable castings shall neither be "over" nor "under" annealed. They must have received their full heat in the oven at least sixty hours after reaching that temperature.

(2) The "saggers" shall not be dumped until the contents shall at least be "black hot."

FINISH.

Castings shall be true to pattern, free from blemishes, scale or shrinkage cracks. A variation of 1-16 of an inch per foot shall be permissible. Founders shall not be held responsible for defects due to irregular cross sections and unevenly distributed metal.

INSPECTION.

The inspector representing the purchaser shall have all reasonable facilities given him by the founder to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made prior to shipment.

* In the amended specifications, adopted by letter-ballot on November 15, 1904, the tensile strength was decreased from 42,000 to 40,000 pounds. No other change was made.—ED.

PROPOSED STANDARD SPECIFICATIONS FOR GRAY IRON CASTINGS.

Process of Manufacture.

Unless furnace iron is specified, all gray castings are understood to be made by the cupola process.

Chemical Properties.

The sulphur contents to be as follows:

Light castings	not over 0.08 per cent.
Medium castings	" 0.10 "
Heavy castings	" 0.12 "

Definition.

In dividing castings into light, medium and heavy classes, the following standards have been adopted.

Castings having any section less than $\frac{1}{2}$ of an inch thick shall be known as *light castings*.

Castings in which no section is less than 2 inches thick shall be known as *heavy castings*.

Medium castings are those not included in the above definitions.

Physical Properties.

Transverse Test. The minimum breaking strength of the "Arbitration Bar" under transverse load shall be not under:

Light castings	2,500 lbs.
Medium castings	2,900 "
Heavy castings	3,300 "

In no case shall the deflection be under .10 of an inch.

Tensile Test. Where specified, this shall not run less than:

Light castings	18,000 lbs. per sq. in.
Medium castings	21,000 " " "
Heavy castings	24,000 " " "

THE "ARBITRATION BAR" AND METHODS OF TESTING.

The quality of the iron going into castings under specification shall be determined by means of the "Arbitration Bar." This is a bar $1\frac{1}{4}$ inches in diameter and 15 inches long. It shall be prepared as stated further on and tested transversely. The tensile test is not recommended, but in case it is called for, the bar as shown in Fig. 1, and turned up from any of the broken pieces of the transverse test shall be used. The expense of the tensile test shall fall on the purchaser.

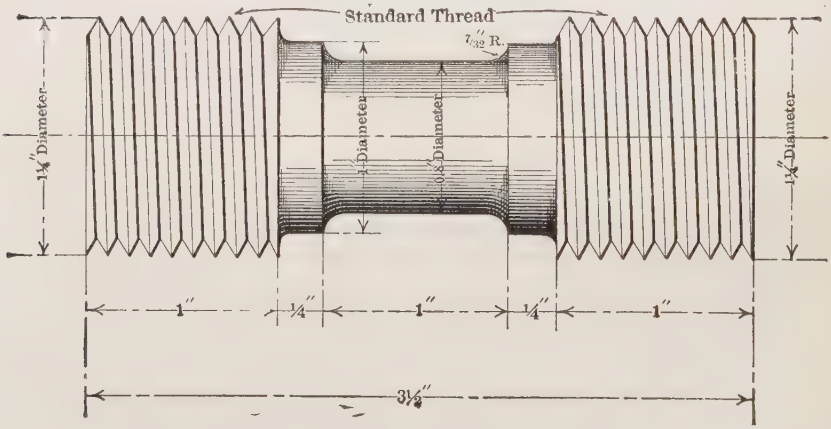

FIG. 1.—ARBITRATION TEST BAR. TENSILE TEST PIECE.

Two sets of two bars shall be cast from each heat, one set from the first and the other set from the last iron going into the castings. Where the heat exceeds twenty tons, an additional set of two bars shall be cast for each twenty tons or fraction thereof above this amount. In case of a change of mixture during the heat, one set of two bars shall also be cast for every mixture other than the regular one. Each set of two bars is to go into a single mold. The bars shall not be rumbled or otherwise treated, being simply brushed off before testing.

The transverse test shall be made on all the bars cast, with supports 12 inches apart, load applied at the middle, and the deflection at rupture noted. One bar of every two of each set

made must fulfill the requirements to permit acceptance of the castings represented.

The mold for the bars is shown in Fig. 2. The bottom of the bar is 1-16 of an inch smaller in diameter than the top, to allow for

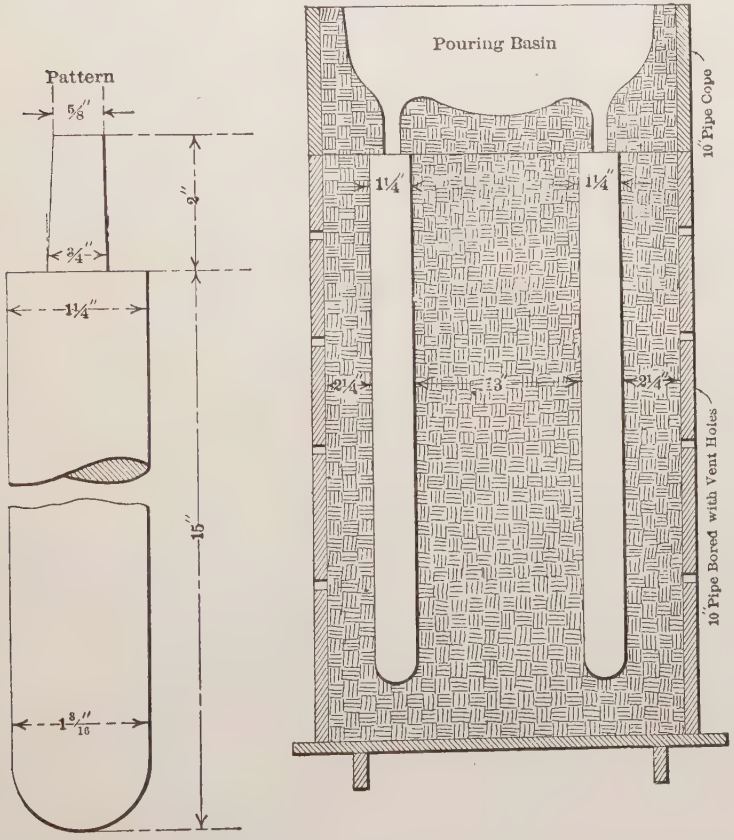

FIG. 2.—MOLD FOR ARBITRATION TEST BAR.
(Not drawn to scale.)

draft and for the strain of pouring. The pattern shall not be rapped before withdrawing. The flask is to be rammed up with green molding sand, a little damper than usual, well mixed and put through a No. 8 sieve, with a mixture of one to twelve bituminous facing. The mold shall be rammed evenly and fairly hard,

thoroughly dried and not cast until it is cold. The test bar shall not be removed from the mold until cold enough to be handled.

SPEED OF TESTING.

The rate of application of the load shall be thirty seconds for a deflection of .10 of an inch.

SAMPLES FOR CHEMICAL ANALYSIS.

Borings from the broken pieces of the "Arbitration Bar" shall be used for the sulphur determinations. One determination for each mold made shall be required. In case of dispute, the standards of the American Foundrymen's Association shall be used for comparison.

FINISH.

Castings shall be true to pattern, free from cracks, flaws and excessive shrinkage. In other respects they shall conform to whatever points may be specially agreed upon.

INSPECTION.

The Inspector shall have reasonable facilities afforded him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall, as far as possible, be made at the place of manufacture prior to shipment.

DISCUSSION.

R. S. MacPherran (by letter).—In the proposed Standard Specifications for Gray Iron Castings occurs the clause:— Mr MacPherran.

"In case of dispute, the standards (for sulphur) of the American Foundrymen's Association shall be used for comparison."

I wish to propose an amendment to substitute in place of the above:—

"In case of dispute, gravimetric determinations shall be made."

In support of this the following is submitted:

"The American Foundrymen's Association Standard most in use contains volatile sulphur 0.038, residual sulphur 0.018, total 0.056.

"This must be used in one of two ways:

"*First, Annealed.*—In this case we assume that all the sulphur is volatilized, absorbed and titrated as H_2S, both in the standard and in the pig iron in question, no allowance being made in either case for residual or insoluble sulphur.

"This in many cases will give good results, but has not yet been tried on a sufficiently great variety of irons to warrant its recommendation as standard by this Society.

"*Second, Unannealed or Direct.*—No pig iron standard run in this way can give close results on all other pig irons. With the above standard for example the iodine solution would be so made up that 5.6 cc. would titrate or neutralize the volatile sulphur from a 5-grain sample.

"It should be noted that the residual sulphur in this standard is 47 per cent. of the volatile and that in using it as above we assume that this is always the case. In effect, therefore, we take the observed or actual volatile sulphur and multiply it by 1.47 and call the product the total sulphur.

"When so used this standard will give close results on samples with that same percentage of residual sulphur, but when used on an iron with little or none, will work a serious injustice. To

Mr. McPherran. illustrate, take an iron containing but 0.002 to 0.006 residual sulphur. An iron of this kind running in volatile 0.038 would be reported total 0.056, where the actual total would be but 0.040 to 0.044."

It seems to me that every pig iron should be judged by itself and have its residual sulphur actually determined by a gravimetric method and not measured or estimated indirectly by the amount in some other iron.

Mr. Moldenke. RICHARD MOLDENKE.—As one of a committee assisting Mr. West in getting up these standards, I would say that the sulphur contents is given in both forms. The volumetric and the gravimetric. The latter is really the correct method to use in case of dispute, the other is only an approximate shop method, which came to the foundry from the steel works where its application is entirely different. Some day we will know more about the nature of the sulphur content in cast iron, and in the meantime it would be best to adhere to the gravimetric sulphur as correct, even if tedious to obtain. Incidentally, it may be said that the standards referred to consist of turnings of castings made under the best conditions possible to insure uniformity. The material itself, after due preparation, is analyzed by four of the best commercial chemists of the country, and hence, has a well-established reputation, besides these, cast-iron standards are the only ones in existence.

STANDARD SPECIFICATIONS FOR FOUNDRY PIG IRON.*

Analysis.

It is recommended that all purchases be made by analysis.

Sampling.

In all contracts where pig iron is sold by chemical analysis, each car load, or its equivalent, shall be considered as a unit. At least one pig shall be selected at random from each four tons of every car load, and so as to fairly represent it.

Drillings shall be taken so as to fairly represent the fracture surface of each pig, and the sample analysed shall consist of an equal quantity of drillings from each pig, well mixed and ground before analysis.

In case of disagreement between buyer and seller, an independent analyst, to be mutually agreed upon, shall be engaged to sample and analyse the iron. In this event one pig shall be taken to represent every two tons.

The cost of this sampling and analysis shall be borne by the buyer if the shipment is proved up to specifications, and by the seller if otherwise.

Allowances and Penalties.

In all contracts, in the absence of a definite understanding to the contrary, a variation of 10 per cent in silicon, either way, and of 0.02 sulphur, above the standard, is allowed.

A deficiency of over 10 per cent and up to 20 per cent, in the silicon, subjects the shipment to a penalty of 4 per cent of the contract price.

* Adopted by letter-ballot on November 15, 1904.—Ed.

BASE ANALYSIS OF GRADES.

In the absence of specifications, the following numbers, known to the trade, shall represent the appended analyses for standard grades of foundry pig irons, irrespective of fracture, and subject to allowances and penalty as above:

Grade.	Per Cent Silicon.	Per Cent Sulphur (volumetric)	Per Cent Sulphur (gravimetric)
No. 1	2.75	0.035	0.045
No. 2	2.25	0.045	0.055
No. 3	1.75	0.055	0.065
No. 4	1.25	0.065	0.075

REPORT OF COMMITTEE C ON STANDARD SPECIFICATIONS FOR CEMENT.

GENERAL OBSERVATIONS.

1. These remarks have been prepared with a view of pointing out the pertinent features of the various requirements and the precautions to be observed in the interpretation of the results of the tests.

2. The Committee would suggest that the acceptance or rejection under these specifications be based on tests made by an experienced person having the proper means for making the tests.

SPECIFIC GRAVITY.

3. Specific gravity is useful in detecting adulteration or underburning. The results of tests of specific gravity are not necessarily conclusive as an indication of the quality of a cement, but when in combination with the results of other tests may afford valuable indications.

FINENESS.

4. The sieves should be kept thoroughly dry.

TIME OF SETTING.

5. Great care should be exercised to maintain the test pieces under as uniform conditions as possible. A sudden change or wide range of temperature in the room in which the tests are made, a very dry or humid atmosphere, and other irregularities vitally affect the rate of setting.

TENSILE STRENGTH.

6. Each consumer must fix the minimum requirements for tensile strength to suit his own conditions. They shall, however, be within the limits stated.

CONSTANCY OF VOLUME.

7. The tests for constancy of volume are divided into two classes, the first normal, the second accelerated. The latter should be regarded as a precautionary test only, and not infallible. So many conditions enter into the making and interpreting of it that it should be used with extreme care.

8. In making the pats the greatest care should be exercised to avoid initial strains due to molding or to too rapid drying-out during the first twenty-four hours. The pats should be preserved under the most uniform conditions possible, and rapid changes of temperature should be avoided.

9. The failure to meet the requirements of the accelerated tests need not be sufficient cause for rejection. The cement may, however, be held for twenty-eight days, and a retest made at the end of that period. Failure to meet the requirements at this time should be considered sufficient cause for rejection, although in the present state of our knowledge it cannot be said that such failure necessarily indicates unsoundness, nor can the cement be considered entirely satisfactory simply because it passes the tests.

STANDARD SPECIFICATIONS FOR CEMENT.

GENERAL CONDITIONS.

1. All cement shall be inspected.

2. Cement may be inspected either at the place of manufacture or on the work.

3. In order to allow ample time for inspecting and testing, the cement should be stored in a suitable weather-tight building having the floor properly blocked or raised from the ground.

4. The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment.

5. Every facility shall be provided by the Contractor and a period of at least twelve days allowed for the inspection and necessary tests.

6. Cement shall be delivered in suitable packages with the brand and name of manufacturer plainly marked thereon.

7. A bag of cement shall contain 94 pounds of cement net. Each barrel of Portland cement shall contain 4 bags, and each barrel of natural cement shall contain 3 bags of the above net weight.

8. Cement failing to meet the seven-day requirements may be held awaiting the results of the twenty-eight day tests before rejection.

9. All tests shall be made in accordance with the methods proposed by the Committee on Uniform Tests of Cement of the American Society of Civil Engineers, presented to the Society January 21, 1903, and amended January 20, 1904, with all subsequent amendments thereto. (See addendum to these specifications.)

10. The acceptance or rejection shall be based on the following requirements:

NATURAL CEMENT.

11. *Definition.* This term shall be applied to the finely pulverized product resulting from the calcination of an argillaceous limestone at a temperature only sufficient to drive off the carbonic acid gas.

SPECIFIC GRAVITY.

12. The specific gravity of the cement thoroughly dried at 100° C., shall be not less than 2.8.

FINENESS.

13. It shall leave by weight a residue of not more than 10% on the No. 100, and 30% on the No. 200 sieve.

TIME OF SETTING.

14. It shall develop initial set in not less than ten minutes, and hard set in not less than thirty minutes, nor more than three hours.

TENSILE STRENGTH.

15. The minimum requirements for tensile strength for briquettes one inch square in cross section shall be within the following limits, and shall show no retrogression in strength within the periods specified: *

Age.	*Neat Cement.*	*Strength.*
24 hours in moist air	.....	50–100 lbs.
7 days (1 day in moist air, 6 days in water)	..	100–200 "
28 days (1 " " " 27 " ")	..	200–300 "
	One Part Cement, Three Parts Standard Sand.	
7 days (1 day in moist air, 6 days in water)	..	25– 75 "
28 days (1 " " " 27 " ")	..	75–150 "

CONSTANCY OF VOLUME.

16. Pats of neat cement about three inches in diameter, one-half inch thick at centre, tapering to a thin edge, shall be kept in moist air for a period of twenty-four hours.

(*a*) A pat is then kept in air at normal temperature.

(*b*) Another is kept in water maintained as near 70° F. as practicable.

* For example the minimum requirement for the twenty-four hour neat cement test should be some specified value within the limits of 50 and 100 pounds, and so on for each period stated.

17. These pats are observed at intervals for at least 28 days, and, to satisfactorily pass the tests, should remain firm and hard and show no signs of distortion, checking, cracking or disintegrating.

PORTLAND CEMENT.

18. *Definition.* This term is applied to the finely pulverized product resulting from the calcination to incipient fusion of an intimate mixture of properly proportioned argillaceous and calcareous materials, and to which no addition greater than 3% has been made subsequent to calcination.

SPECIFIC GRAVITY.

19. The specific gravity of the cement, thoroughly dried at 100° C., shall be not less than 3.10.

FINENESS.

20. It shall leave by weight a residue of not more than 8% on the No. 100, and not more than 25% on the No. 200 sieve.

TIME OF SETTING.

21. It shall develop initial set in not less than thirty minutes, but must develop hard set in not less than one hour, nor more than ten hours.

TENSILE STRENGTH.

22. The minimum requirements for tensile strength for briquettes one inch square in section shall be within the following limits, and shall show no retrogression in strength within the periods specified:*

Age.	*Neat Cement.*	*Strength.*
24 hours in moist air	.....	150–200 lbs.
7 days(1 day in moist air, 6 days in water)	..	450–550 "
28 days(1 " " " 27 " ")	..	550–650 "

* For example the minimum requirement for the twenty-four hour neat cement test should be some specified value within the limits of 150 and 200 pounds, and so on for each period stated.

One Part Cement, Three Parts Standard Sand.

7 days (1 day in moist air, 6 days in water) 150–200 lbs.

28 days (1 " " " 27 " ") 200–300 "

CONSTANCY OF VOLUME.

23. Pats of neat cement about three inches in diameter, one-half inch thick at the centre, and tapering to a thin edge, shall be kept in moist air for a period of twenty-four hours.

(*a*) A pat is then kept in air at normal temperature and observed at intervals for at least 28 days.

(*b*) Another pat is kept in water maintained as near 70° F. as practicable, and observed at intervals for at least 28 days.

(*c*) A third pat is exposed in any convenient way in an atmosphere of steam, above boiling water, in a loosely closed vessel for five hours.

24. These pats, to satisfactorily pass the requirements, shall remain firm and hard and show no signs of distortion, checking, cracking or disintegrating.

SULPHURIC ACID AND MAGNESIA.

25. The cement shall not contain more than 1.75% of anhydrous sulphuric acid (SO 3), nor more than 4% of magnesia (MgO).

Submitted on behalf of the committee.

GEORGE F. SWAIN, *Chairman.*
GEORGE S. WEBSTER, *Vice-Chairman.*
RICHARD L. HUMPHREY, *Secretary.*

F. H. Bainbridge.
Booth, Garrett & Blair.
C. W. Boynton.
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A. F. Gerstell.
Edward M. Hagar.
W. H. Harding.
Olaf Hoff.
Lathbury and Spackman.
Robert W. Lesley.
F. H. Lewis.
John B. Lober.
Andreas Lundteigen.
Charles F. McKenna.
W. W. Maclay.
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American Institute of Architects, W. S. Eames, *President.*
American Railway Engineering and Maintenance of Way Association, H. G. Kelly, *Vice-President.*

ADDENDUM

ABSTRACT OF METHODS RECOMMENDED BY THE SPECIAL COMMITTEE ON UNIFORM TESTS OF CEMENT OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

SAMPLING.

1.—*Selection of Sample.*—The sample shall be a fair average of the contents of the package; it is recommended that, where conditions permit, one barrel in every ten be sampled.

2.—All samples should be passed through a sieve having twenty meshes per linear inch, in order to break up lumps and remove foreign material; this is also a very effective method for mixing them together in order to obtain an average. For determining the characteristics of a shipment of cement, the individual samples may be mixed and the average tested; where time will permit, however, it is recommended that they be tested separately.

3.—*Method of Sampling.*—Cement in barrels should be sampled through a hole made in the center of one of the staves, midway between the heads, or in the head, by means of an auger or a sampling iron similar to that used by sugar inspectors. If in bags, it should be taken from surface to center.

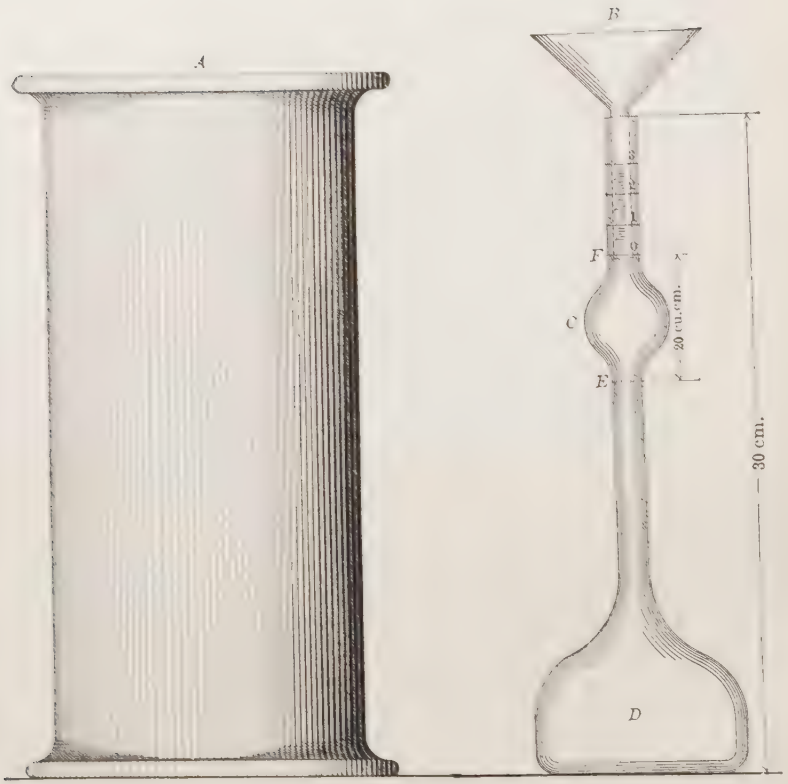
CHEMICAL ANALYSIS.

4.—*Method.*—As a method to be followed for the analysis of cement, that proposed by the Committee on Uniformity in the Analysis of Materials for the Portland Cement Industry, of the New York Section of the Society for Chemical Industry, and published in the *Journal* of the Society for January 15, 1902, is recommended.

SPECIFIC GRAVITY.

5.—*Apparatus and Method.*—The determination of specific gravity is most conveniently made with Le Chatelier's apparatus. This consists of a flask (*D*), Fig. 1, of 120 cu. cm. (7.32 cu. ins.) capacity, the neck of which is about 20 cm. (7.87 ins.) long; in the middle of this neck is a bulb (*C*), above and below which are two marks (*F*) and (*E*); the volume between these marks is 20 cu. cm. (1.22 cu. ins.). The neck has a diameter of about 9 mm. (0.35 in.), and is graduated into tenths of cubic centimeters above the mark (*F*).

6.—Benzine (62° Baumé naphtha), or kerosene free from water should be used in making the determination



LE CHATELIER'S SPECIFIC GRAVITY APPARATUS
FIG. 1.

7.—The specific gravity can be determined in two ways:

(1) The flask is filled with either of these liquids to the lower mark (*E*), and 64 gr. (2.25 oz.) of powder, previously dried at 100° C. (212° F.) and cooled to the temperature of the liquid, is gradually introduced through the funnel (*B*) [the stem of which extends into the flask to the top of the bulb (*C*)], until the upper mark (*F*) is reached. The difference in weight between the cement remaining and the original quantity (64 gr.) is the weight which has displaced 20 cu. cm.

8.—(2) The whole quantity of the powder is introduced, and the level of the liquid rises to some division of the graduated neck. This reading plus 20 cu. cm. is the volume displaced by 64 gr. of the powder.

9.—The specific gravity is then obtained from the formula:

$$\text{Specific Gravity} = \frac{\text{Weight of Cement}}{\text{Displaced Volume.}}$$

10.—The flask, during the operation, is kept immersed in water in a jar (*A*), in order to avoid variations in the temperature of the liquid. The results should agree within 0.01.

11.—A convenient method for cleaning the apparatus is as follows: The flask is inverted over a large vessel, preferably a glass jar, and shaken vertically until the liquid starts to flow freely; it is then held still in a vertical position until empty; the remaining traces of cement can be removed in a similar manner by pouring into the flask a small quantity of clean liquid and repeating the operation.

FINENESS.

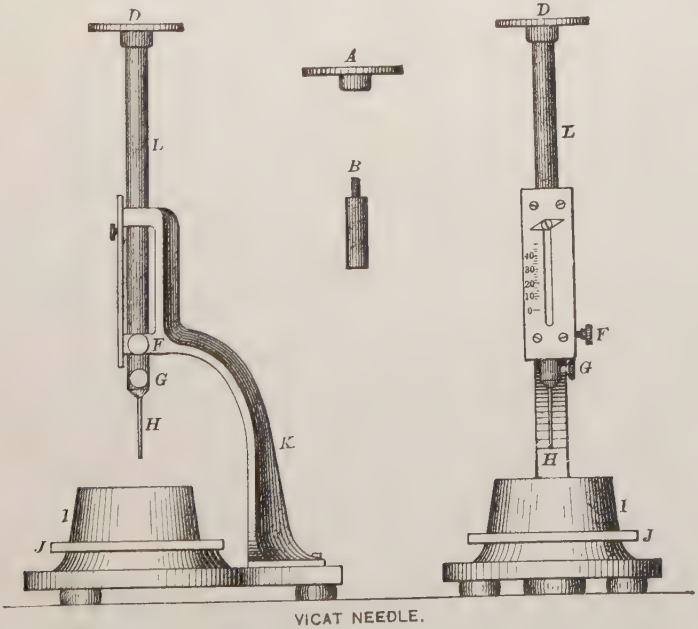
12.—*Apparatus.*—The sieves should be circular, about 20 cm. (7.87 ins.) in diameter, 6 cm. (2.36 ins.) high, and provided with a pan, 5 cm. (1.97 ins.) deep, and a cover.

13.—The wire cloth should be woven (not twilled) from brass wire having the following diameters:

No. 100, 0.0045 in.; No. 200, 0.0024 in.

14.—This cloth should be mounted on the frames without distortion; the mesh should be regular in spacing and be within the following limits:

No. 100, 96 to 100 meshes to the linear inch.
No. 200, 188 to 200 " " " "



VICAT NEEDLE.
FIG. 2.

15.—Fifty gram (1.76 oz.) or 100 gr. (3.52 oz.) snould be used for the test, and dried at a temperature of 100° C. (212° F.) prior to sieving.

16.—*Method.*—The thoroughly dried and coarsely screened sample is weighed and placed on the No. 200 sieve, which, with pan and cover attached, is held in one hand in a slightly inclined position, and moved forward and backward, at the same time striking the side gently with the palm of the other hand, at the rate of about 200 strokes per minute. The operation is continued until not more than one-tenth of 1 per cent passes through after one minute of continuous sieving. The residue is weighed, then placed on the No. 100 sieve and the operation repeated. The work may be expedited by placing in the sieve a small quantity of large shot. The results should be reported to the nearest tenth of 1 per cent.

Normal Consistency.

17.—*Method.*—This can best be determined by means of *Vicat Needle Apparatus*, which consists of a frame (*K*), Fig. 2, bearing a movable rod (*L*), with the cap (*A*) at one end, and at the other the cylinder (*B*), 1 cm. (0.39 in.) in diameter, the cap, rod and cylinder weighing 300 gr. (10 58 oz.). The rod, which can be held in any desired position by a screw (*F*), carries an indicator, which moves over a scale (graduated to centimeters) attached to the frame (*K*). The paste is held by a conical, hard-rubber ring (*I*), 7 cm. (2.76 ins.) in diameter at the base, 4 cm. (1.57 ins.) high, resting on a glass plate (*J*). about 10 cm. (3.94 ins.) square.

18.—In making the determination, the same quantity of cement as will be subsequently used for each batch in making the briquettes (but not less than 500 grams) is kneaded into a paste, as described in paragraph 39, and quickly formed into a ball with the hands, completing the operation by tossing it six times from one hand to the other, maintained 6 ins. apart; the ball is then pressed into the rubber ring, through the larger opening, smoothed off, and placed (on its large end) on a glass plate and the smaller end smoothed off with a trowel; the paste, confined in the ring, resting on the plate, is placed under the rod bearing the cylinder, which is brought in contact with the surface and quickly released.

19.—The paste is of normal consistency when the cylinder penetrates to a point in the mass 10 mm. (0.39 in.) below the top of the ring. Great care must be taken to fill the ring exactly to the top.

20.—The trial pastes are made with varying percentages of water until the correct consistency is obtained

NOTE. The Committee on Standard Specifications inserts the following table for temporary use to be replaced by one to be devised by the Committee of the American Society of Civil Engineers.

PERCENTAGE OF WATER FOR STANDARD MIXTURES.

Neat	1-1	1-2	1-3	1-4	1-5	Neat	1-1	1-2	1-3	1-4	1-5
18	12.0	10.0	9.0	8.4	8.0	33	17.0	13.3	11.5	10.4	9.6
19	12.3	10.2	9.2	8.5	8.1	34	17.3	13.6	11.7	10.5	9.7
20	12.7	10.4	9.3	8.7	8.2	35	17.7	13.8	11.8	10.7	9.9
21	13.0	10.7	9.5	8.8	8.3	36	18.0	14.0	12.0	10.8	10.0
22	13.3	10.9	9.7	8.9	8.4	37	18.3	14.2	12.2	10.9	10.1
23	13.7	11.1	9.8	9.1	8.5	38	18.7	14.4	12.3	11.1	10.2
24	14.0	11.3	10.0	9.2	8.6	39	19.0	14.7	12.5	11.2	10.3
25	14.3	11.6	10.2	9.3	8.8	40	19.3	14.9	12.7	11.3	10.4
26	14.7	11.8	10.3	9.5	8.9	41	19.7	15.1	12.8	11.5	10.5
27	15.0	12.0	10.5	9.6	9.0	42	20.0	15.3	13.0	11.6	10.6
28	15.3	12.2	10.7	9.7	9.1	43	20.3	15.6	13.2	11.7	10.7
29	15.7	12.5	10.8	9.9	9.2	44	20.7	15.8	13.3	11.9	10.8
30	16.0	12.7	11.0	10.0	9.3	45	21.0	16.0	13.5	12.0	11.0
31	16.3	12.9	11.2	10.1	9.4	46	21.3	16.1	13.7	12.1	11.1
32	16.7	13.1	11.3	10.3	9.5						

	1 to 1	1 to 2	1 to 3	1 to 4	1 to 5
Cement	500	333	250	200	167
Sand	500	666	750	800	833

TIME OF SETTING.

21.—*Method.*—For this purpose the Vicat Needle, which has already been described in paragraph 17, should be used.

22.—In making the test, a paste of normal consistency is molded and placed under the rod (*L*), Fig. 2, as described in paragraph 18; this rod, bearing the cap (*D*) at one end and the needle (*H*), 1 mm. (0.039 in.) in diameter, at the other, weighing 300 gr. (10.58 oz.). The needle is then carefully brought in contact with the surface of the paste and quickly released.

23.—The setting is said to have commenced when the needle ceases to pass a point 5 mm. (0.20 in.) above the upper surface of the glass plate, and is said to have terminated the moment the needle does not sink visibly into the mass.

24.—The test pieces should be stored in moist air during the test; this is accomplished by placing them on a rack over water contained in a pan and covered with a damp cloth, the cloth to be kept away from them by means of a wire screen; or they may be stored in a moist box or closet.

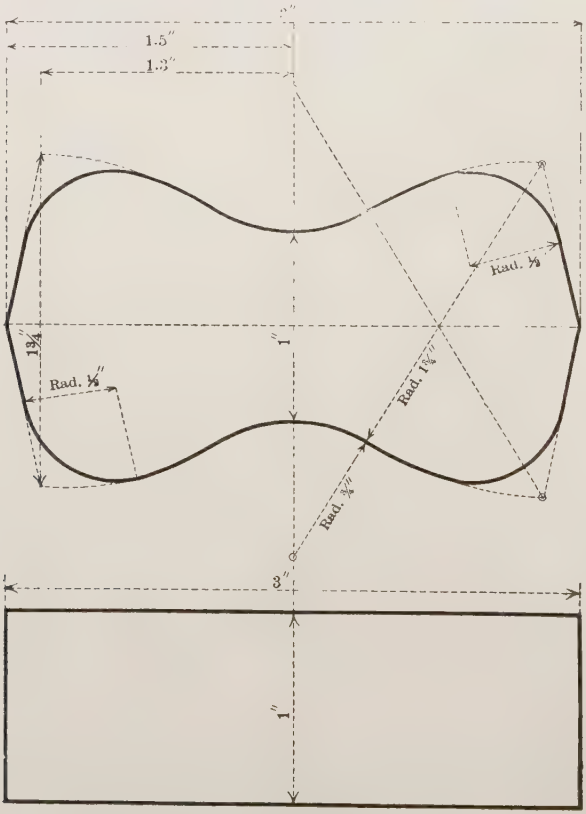
25.—Care should be taken to keep the needle clean, as the collection of cement on the sides of the needle retards the penetration, while cement on the point reduces the area and tends to increase the penetration.

26.—The determination of the time of setting is only approximate, being materially affected by the temperature of the mixing water, the temperature and humidity of the air during the test, the percentage of water used, and the amount of molding the paste receives.

STANDARD SAND.

27.—For the present, the Committee recommends the natural sand from Ottawa, Ill., screened to pass a sieve having 20 meshes per linear inch and retained on a sieve having 30 meshes per linear inch; the wires to have diameters of 0.0165 and 0.0112 in., respectively, *i. e.*, half the width of the opening in each case. Sand having passed the No. 20 sieve shall be considered standard when not more than 1 per cent passes a No. 30 sieve after one minute continuous sifting of a 500-gram sample.

28.—The Sandusky Portland Cement Company, of Sandusky, Ohio, has agreed to undertake the preparation of this sand and to furnish it at a price only sufficient to cover the actual cost of preparation.



DETAILS FOR BRIQUETTE.

FIG. 8.

Form of Briquette.

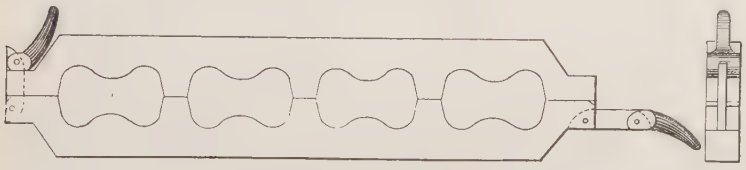
29.—While the form of the briquette recommended by a former Committee of the Society is not wholly satisfactory, this Committee is not prepared to suggest any change, other than rounding off the corners by curves of ½-in. radius, Fig. 3.

Molds.

30.—The molds should be made of brass, bronze or some equally non-corrodible material, having sufficient metal in the sides to prevent spreading during molding.

31.—Gang molds, which permit molding a number of briquettes at one time, are preferred by many to single molds; since the greater quantity of mortar that can be mixed tends to produce greater uniformity in the results. The type shown in Fig. 4 is recommended.

32.—The molds should be wiped with an oily cloth before using.



DETAILS FOR GANG MOULD.

Fig. 4.

Mixing.

33.—All proportions should be stated by weight; the quantity of water to be used should be stated as a percentage of the dry material.

34.—The metric system is recommended because of the convenient relation of the gram and the cubic centimeter.

35.—The temperature of the room and the mixing water should be as near 21° C. (70° F.) as it is practicable to maintain it.

36.—The sand and cement should be thoroughly mixed dry. The mixing should be done on some non-absorbing surface, preferably plate glass. If the mixing must be done on an absorbing surface it should be thoroughly dampened prior to use.

37.—The quantity of material to be mixed at one time depends on the number of test pieces to be made; about 1,000 gr. (35.28 oz.) makes a convenient quantity to mix, especially by hand methods.

38.—*Method.*—The material is weighed and placed on the mixing table, and a crater formed in the center, into which the proper percentage of clean water is poured; the material on the outer edge is turned into the crater by the aid of a trowel. As soon as the water has been absorbed, which should not require more than one minute, the operation is completed by vigorously kneading with the hands for an additional 1½ minutes, the process being similar to that used in kneading dough. A sand-glass affords a convenient guide for the time of kneading. During the operation of mixing, the hands should be protected by gloves, preferably of rubber.

Molding.

39.—Having worked the paste or mortar to the proper consistency, it is at once placed in the molds by hand.

40.—*Method.*—The molds should be filled at once, the material pressed in firmly with the fingers and smoothed off with a trowel without ramming; the material should be heaped up on the upper surface of the mold, and, in smoothing off, the trowel should be drawn over the mold in such a manner as to exert a moderate pressure on the excess material. The mold should be turned over and the operation repeated.

41.—A check upon the uniformity of the mixing and molding is afforded by weighing the briquettes just prior to immersion, or upon removal from the moist closet. Briquettes which vary in weight more than 3 per cent from the average should not be tested.

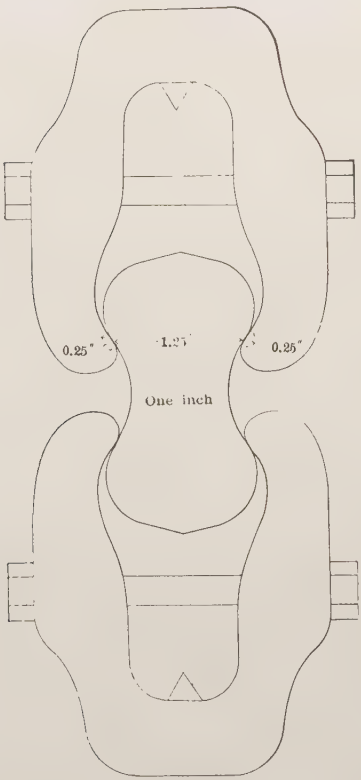


FIG. 5.

Storage of the Test Pieces.

42.—During the first 24 hours after molding, the test pieces should be kept in moist air to prevent them from drying out.

43.—A moist closet or chamber is so easily devised that the use of the damp cloth should be abandoned if possible. Covering the test pieces with a damp cloth is objectionable, as commonly used, because the cloth may dry out unequally, and in consequence the test pieces are not all maintained under the same condition. Where a moist closet is not available, a cloth may be used and kept uniformly wet by immersing the ends in water. It should be kept from direct contact with the test pieces by means of a wire screen or some similar arrangement.

44.—A moist closet consists of a soapstone or slate box, or a metal-lined wooden box—the metal lining being covered with felt and this felt kept wet. The bottom of the box is so constructed as to hold water, and the sides are provided with cleats for holding glass shelves on which to place the briquettes. Care should be taken to keep the air in the closet uniformly moist.

45.—After 24 hours in moist air, the test pieces for longer periods of time should be immersed in water maintained as near 21° C. (70° F.) as practicable; they may be stored in tanks or pans, which should be of non-corrodible material.

Tensile Strength.

46.—The tests may be made on any standard machine. A solid metal clip, as shown in Fig. 5, is recommended. This clip is to be used without cushioning at the points of contact with the test specimen. The bearing at each point of contact should be $\frac{1}{4}$ in. wide, and the distance between the center of contact on the same clip should be $1\frac{1}{4}$ ins.

47.—Test pieces should be broken as soon as they are removed from the water. Care should be observed in centering the briquettes in the testing machine, as cross-strains, produced by improper centering, tend to lower the breaking strength. The load should not be applied too suddenly, as it may produce vibration, the shock from which often breaks the briquette before the ultimate strength is reached. Care must be taken that the clips and the sides of the briquette be clean and free from grains of sand or dirt, which would prevent a good bearing. The load should be applied at the rate of 600 lbs. per minute. The average of the briquettes of each sample tested should be taken as the test, excluding any results which are manifestly faulty.

Constancy of Volume.

48.—*Methods.*—Tests for constancy of volume are divided into two classes: (1) normal tests, or those made in either air or water maintained at about 21° C. (70° F.), and (2) accelerated tests, or those made in air, steam or water at a temperature of 45° C. (115° F.) and upward. The test pieces should be allowed to remain 24 hours in moist air before immersion in water or steam, or preservation in air.

49.—For these tests, pats about $7\frac{1}{2}$ cm. (2.95 ins.) in diameter, $1\frac{1}{4}$ cm. (0.49 in.) thick at the center, and tapering to a thin edge, should be made, upon a clean glass plate [about 10 cm. (3.94 ins.) square], from cement paste of normal consistency.

50.—*Normal Test.*—A pat is immersed in water maintained as near 21° C. (70° F.) as possible for 28 days, and observed at intervals. A similar pat is maintained in air at ordinary temperature and observed at intervals.

51.—*Accelerated Test.*—A pat is exposed in any convenient way in an atmosphere of steam, above boiling water, in a loosely closed vessel.

52.—To pass these tests satisfactorily, the pats should remain firm and hard, and show no signs of cracking, distortion or disintegration.

53.—Should the pat leave the plate, distortion may be detected best with a straight-edge applied to the surface which was in contact with the plate.

DISCUSSION.

Mr. McKenna. CHARLES F. MCKENNA.—Rather than send these specifications out for a letter-ballot, it would appear to me to be wiser to refer them back to the committee. After an expression of the views of the large number of members of the committee, and others deeply interested in the subject present here, I think the committee will have more light on which to act. One reason why they should not go forward is on account of the difficulty which arises when once specifications get the name of "standard" and get into the literature. We would hear about their deficiencies, whatever they may be, for the next ten years.

I therefore move that these specifications be referred back to the committee for further consideration and amendment. (Motion seconded.)

Mr. Humphrey. RICHARD L. HUMPHREY.—I should like to say that I consider Dr. McKenna's motion to refer the specifications back to the committee a very unwise move. It would practically nullify the results of the committee's labors, and would again open up the whole subject to discussion. The committee does not feel that these specifications are perfect; I do not think that we have attained the ideal; but after many meetings, these specifications have been evolved. In the attainment of any standard, it is necessary to begin with something, even though it be defective. These specifications are a start, and it is not the intention of the committee to consider them final. The committee will be continued, and if it is found that the specifications have defects, the committee is prepared to remedy such defects. I think these specifications for a beginning are unusually fair. The engineer need have no hesitancy in using them, for it will enable him to obtain cements of the highest grade. You can not evolve anything that is free from criticism. The committee has tried to condense in a single specification the ideas of thirty-two members, consisting of consumers, manufacturers, and inspectors. A number of laboratory meetings have been held, in which experiments were made with a view of

determining the degree of uniformity attainable with standard methods. Samples of five brands of Portland and four brands of natural cement were sent to some thirty laboratories, embracing the most important ones, with a request that they be tested in full accordance with the requirements prescribed by the Committee on Uniform Methods of Tests of the American Society of Civil Engineers. The results of these tests were compiled, and form the basis of the requirements of these specifications. The present requirements were agreed on after a number of meetings, at which each requirement was thoroughly discussed. The present specifications are the result of these discussions. Mr. Humphrey.

It is for these reasons that I think it would be very unwise to refer the specifications back to the committee, and feel that this motion should not pass. While conceding that the specifications are not perfect, they are nevertheless the best that can be agreed on at the present time. The specification should be adopted with the understanding that they be amended by the committee wherever found to be defective.

MR. MCKENNA.—My objection to these specifications is based on their faulty definition of Portland cement and to their general indefiniteness of expression. Mr. McKenna.

CHARLES S. CHURCHILL.—It seems to me that we are putting ourselves in rather a wrong position with reference to one other strong society, in going forward and adopting specifications without reference to that other strong society. I refer to the American Railway Engineering and Maintenance of Way Association. As I understand it, it was once proposed to work in harmony. I think we cannot work in harmony unless one society criticises the acts of the other and suggests improvements thereon. I think this committee is making a mistake in giving us full and complete specifications with no criticism of those of the other society or suggestions therefrom. The result will probably be, that there will be two specifications before this country, both backed up by strong societies. If, on the other hand, we adopt the plan that was suggested two or three years ago, namely, that if one society produced a specification, the corresponding committee in the other society should make objections to some special points, that they thought were not completely covered, and get the committees together and see Mr. Churchill.

Mr. Churchill. if we could not harmonize these objections, the result will be something of great value to the whole country. Now, if I understand the recommendation of our committee correctly, we are about to separate with the result of two specifications. I think we should refer this back to the committee, but with instructions to get the two cement specification committees together. Let us give this society very great weight—let us give the other society due consideration also.

Mr. Humphrey MR. HUMPHREY.—The Committee on Masonry of the American Railway Engineering and Maintenance of Way Association appointed a sub-committee of three, which attended the meeting at which these specifications were adopted. The members of this sub-committee not only voted favorably on the adoption of these specifications, but they also expressed themselves entirely satisfied with them.

It is my own personal judgment that the specifications are strong ones, and that the cement which meets its requirements, is above the average; it is a cement of first-class quality, of the highest grade. The explanatory clauses are in no way derogatory of the specifications.

Mr. Webster GEORGE S. WEBSTER.—I feel that these specifications are most excellent ones on the whole. They are the result of the labors of the committee covering a long period, and based upon an extended series of tests. I believe they form an excellent nucleus for more perfect specifications as we gain further information.

I understand it is the purpose to continue the committee; that any criticisms may be considered and amendments proposed from time to time. I hope that the Society may see its way clear to pass these specifications to a vote in order to give a foundation for future work. I know from experience in using large quantities of cement that most excellent results may be obtained from material which meets the requirements of these specifications. I should regret to see the tensile strength made much higher.

Mr. Matcham. CHARLES A. MATCHAM.—While there are some points in these specifications which may not meet our views altogether there is one in regard to tests, which is not very clear, I refer to the 24-hour, 7-day and 28-day tests. The specifications state:—

NEAT CEMENT.

	Strength	Mr. Matcham.
24 hours in moist air,	150–200 lbs.	
7 days (1 day in air, 6 days in water),	450–550 "	
28 " (1 " " " 27 " " ")	550–650 "	

ONE PART CEMENT, THREE PARTS SAND.

7 days (1 day in moist air, 6 days in water),	150–200 lbs.
28 " (1 " " " " 27 " " ")	200–300 "

This is somewhat misleading, and may be construed to mean that the test must give a result within the limits of say 450 to 550 pounds for 7 days, which is not the intention. If a clause were inserted explaining more fully the intended meaning of the marginal figures, I should favor a vote on these specifications.

MR. HUMPHREY.—I should not like to see that passed as a motion. I do not think it would be wise to take the maximum figures and say that it is a high grade cement. I think if it is necessary for an explanatory clause to be inserted, stating just what these figures mean, it can be done without any action of this body, and I will add further that such a clause will be put in. Mr. Humphrey

Mr. McKenna's motion was put to vote and lost.

A motion by Mr. Humphrey that the proposed specifications be sent out to letter-ballot for adoption by the Society was seconded and carried.

JOHN G. BROWN (by letter).—In commenting upon the proposed Standard Specifications for Cement, it should be borne in mind that the testing of cement in the vast majority of cases is an attempt to form an idea of its soundness from the accelerated test and of its purity and value as a constructive agent entirely from its physical strength as determined by tension. The chemical testing of cement from the standpoint of the user is very rarely practiced, even among such large users of cement as the Engineer Corps, U. S. Army. There are consequently few laboratories in the country that are equipped with the proper apparatus, and who make a specialty of conducting intelligent chemical analysis of cement. Even in such laboratories, resort to chemical analysis is only made when the tensile tests do not show the customary values. On the other hand, there is hardly a work of any con- Mr. Brown.

Mr. Brown.

siderable size on which the physical testing of cement is not conducted. With this in view and referring to the specifications of the committee, it will be noticed that no chemical requirements or restrictions other than those for sulphuric anhydride (SO_3) or magnesia (Mgo) are mentioned. The cement therefore will be either accepted or rejected on purely physical tests, excepting in respect to SO_3 and Mgo. The specification for tensile strength should therefore be set at so high a figure as to preclude as far as possible the substitution of adulterated or blended (mixture of natural and Portland) cement.

Since the recommendations of the Committee on Uniformity of Cement Tests of the American Society of Civil Engineers are attached as an addendum to the report, the use of Ottawa sand appears to be obligatory in all sand tests.

Cement tested with Ottawa sand always shows greater strength, varying with the fineness of the cement, than if it be tested with crushed quartz. The excess may be as high as 20 to 40 per cent. The comparison is more marked in the case of a coarse than a fine cement. The reason for this difference is due to the shape of the sand grains. The grains of the Ottawa sand being round, it compacts much more closely and has a lower percentage of voids than crushed quartz. The latter is composed of sharp and angular grains which mass and wedge, and has therefore a larger percentage of voids. As a finely ground cement makes with water a greater amount of paste than a coarsely ground one, naturally, when comparing results obtained with Ottawa sand and crushed quartz, the effect of the sand is more marked when using a coarsely ground cement, and any specification requiring the use of this sand should specify 20 to 30 per cent higher values than for crushed quartz. The comparative influence of Ottawa sand and crushed quartz on the tensile strength of Portland cement mortar is exhibited in the following table:

TENSILE STRENGTH OF 1–3 PORTLAND CEMENT MORTAR IN POUNDS PER SQUARE INCH AT 7 DAYS.

	Crushed Quartz.	Ottawa Sand.
Coarsely ground; average of 5 tests	168	251
Finely ground; average of 5 tests	233	274
Finely ground; average of 3 tests	251	330
Finely ground; average of 5 tests	296	302

Mr. Brown.

I should object very strongly to setting the requirements for tensile strength in these specifications at less than 200 pounds at seven days and 300 pounds at 28 days. I believe that few men of wide experience would base specification contemplating the use of crushed quartz, 1–3 mortar, at less than 175 or 200 pounds at 7 days, as it is well known that any straight Portland cement will exceed these limits. Yet here we have specified values of 150 to 200 pounds based upon a sand (Ottawa recommended by this committee) that gives 20 to 40 per cent greater strength than standard crushed quartz.

If we take the committee's highest figures of 200 pounds at 7 days and 300 pounds at 28 days, and reduce them 20 per cent, for crushed quartz we have 167 and 200 pounds, respectively, or values very much below the limits that we would expect an ordinary straight Portland to exceed. If we reduce their lowest figures, 150 pounds at 7 days and 200 pounds at 28 days, we obtain 125 and 167 pounds, or values that are ridiculous; and can be met by blends of 50 per cent natural, 50 per cent of Portland, with ease. In adopting other than the highest figures recommended by the committee instead of encouraging the manufacture of straight Portland cement, we would be encouraging the adulteration of Portland cement.

It is a well-known fact among manufacturers that at least three of the larger manufacturers of cement and some of the smaller ones of the Lehigh Valley district make a specialty of blending cement in various proportions and shipping it as Portland to meet the majority of specifications under which they supply cement, and they can and do make blends that will exceed the 150 pounds (1–3 Ottawastand) called for by these specifications. It is true these mixtures would not meet the specific gravity requirements of 3.10, but paragraph 3, "General Observations," states that this clause is not conclusive in itself, and since the committee has not specified any method of detecting blending, or other adulteration, naturally the engineer not being able to detect the blending would not have sufficient grounds upon which to condemn this cement.

Referring to paragraph 6, "General Observations," there should be no other conditions assumed by the committee than straight commercial Portland cement. If this is too costly or strong

Mr. Brown.

for the engineer, let him use larger proportions of sand and stone in his mortar and concrete, thereby obtaining for less money the same strength as by the use of inferior or blended cement with less sand; or else let him buy natural and Portland cement separately and mix these as desired.

The engineer is rarely aware that by making his requirements low for tensile strength he is encouraging adulteration and preventing competition with honest manufacturers who make nothing but straight Portland cement, and are therefore unable to compete in price against the manufacturers who adulterate by adding natural cement or native rock and ship it labeled as Portland.

Referring to paragraph 7, "General Observations:" I have given the quesion of accelerated tests very careful consideration and my experience has taught me to look upon the results of the accelerated test, used in conjunction with the sulphuric anhydride analysis, to be the best guide in accepting a consignment of cement. Any cement failing in such a mild test as 5 hours in steam should be condemned on the first trial. But if the manufacturer wishes to have his cement retested, let him pay for the demurrage and storage while it is becoming seasoned; or else let him season it before delivery, which is the proper practice. Contrary to the understanding of many, blends to the extent of 40 per cent will pass the accelerated test prescribed by this committee with ease. In view of the rapid development in the use of reinforced concrete above ground and in dry situations, the accelerated test should be rigidly insisted upon.

Referring to paragraph 9, "General Observations:" To make a Portland cement that will pass an accelerated test it is necessary that the raw product shall be exactly proportioned, finely ground, properly burnt and properly seasoned. This can be done and will furnish the best obtainable material. The product of some mills invariably passes the accelerated test because of the intelligent supervision and great care exercised in the manufacture added to ample storage facilities. The majority of mills make cement that will pass this test, but when cement is in demand they do not give it sufficient time to season. There are certain mills, however, whose product when first delivered invariably fails to pass the accelerated test. These mills do not take the same care in the grinding of the raw product and the handling

and rehandling necessary in storing it to season. That being an expensive process, they always fall back on the "retest at 28 days" clause, filling the storehouse on the works with green cement to age, to the annoyance and expense of the engineer or contractor and to the serious delay of the work. Mr Brown

As an illustration of the annoyance and expense in connection with the "retest at 28 days period," I might mention the following experience with two brands of cement. I have received over 200 cars (over 40,000 barrels) of Brand No. 1 and have never had one to fail in the accelerated test. Of Brand No. 2 I found 6 cars out of 15 cars to fail; the manufacturer of course applying for the 28 days retest, and as is usual, one-half passing the retest satisfactorily. Consider, however, the delay and annoyance caused to the contractor in awaiting the ripening of this cement.

By inspection of the mill of Brand No. 1, we found storage facilities far in excess of those in the case of Brand No. 2. In the mill of Brand No. 1 every step of the process of manufacture was under the most careful supervision, with a view of producing a cement perfect in composition and properly seasoned so that it would boil. It is needless to add that the manufacture cost considerably more than in the case of Brand No. 2.

As a comparison between a cement that will boil and one that will not, with Brand No. 1 there has never been a failure in a normal pat, kept either in air or water, and I have examined over 280 of them once a week for over eighteen months. Of Brand No. 2 I have never known one that failed in the accelerated test that did not show marked signs of failure within six months to one year.

Regarding the proper interpretations of results, paragraph 7, "General Observations", I am sure it requires no more knowledge or mental training, if as much, to interpret the results of the accelerated test than it does the results of the so-called normal pats, because the failures in the accelerated test are generally so decidedly marked that there can be no question of failure. This failure presents always a decided contrast to what the specimen was before being placed in the bath, while the changes in the normal pats are so gradual and so very very slow, many of them not showing marked signs of failure in less than three months, and occasionally one or more years. This disintegration being so slow,

Mr. Brown. it requires a clever prophet of much judgment and experience to state positively at a period of three months, not to say 28 days, whether it will fail or not, and yet in the end (6 months to 3 or 4 years) the normal pats may have fallen to pieces.

My objections to the specifications may be summarized as follows:

The committee have written a specification that fails to specify:

1. A straight Portland cement (paragraph 18, Standard Specifications, means well, but the engineer is not at the mill when the cement is made, and is not equipped with chemical apparatus).

2. A properly burnt cement (see restriction about specific gravity test, paragraph 3, "General Observations").

3. A seasoned cement (not condemned on first trial in accelerated test).

4. A definite standard of strength (paragraph 22, Standard Specifications).

5. 1–3 Ottawa sand strength of high enough value to prevent the substitution of blended cement for Portland. Blended cement, varying from 50 to 20 per cent of natural to Portland, can be forced upon the engineer depending on the figure he selects for his specifications between the limits of 150 to 200 pounds for 1–3 Ottawa sand at 7 days. To show how easy this is, I submit a table made from tests on a blend of 50 to 50 per cent tested 1–3 with Ottawa sand in exactly the manner specified by the committee. The engineer could be induced to accept this blend cement on the following grounds:

1. Satisfactory fineness.
2. Satisfactory time of setting.
3. Satsifactory tensile strength 19 pounds more than specified.
4. Excellent increase in tensile strength.
5. Accelerated test satisfactory.
6. SO_3 satisfactory.
7. M G O not determined.
8. Low in specific gravity, but not corroborated by other tests.

Result—An honest manufacturer cannot compete; the engineer gets low prices and low-grade cement.)

TESTS SHOWING THE EFFECTS OF BLENDING "PORTLAND CEMENT" WITH NATURAL CEMENT. Mr. Brown.

Sample No. 1, 100 per cent Portland (Vulcanite Portland Cement.

Sample No. 2, 50 per cent Portland and 50 per cent natural.

Sample No. 4, 100 per cent natural (Saylor's Hydraulic Cement).

	TENSILE STRENGTH lbs. per sq. in.		
1–3 *Ottawa Sand:*	Sample No. 1	Sample No. 2	Sample No. 4
One day moist air	107	73	34
One day moist air, 6 days water	305	169	55
One day moist air, 27 days water	422	245	121
Fineness:			
Retained on No. 100 sieve	8.5	7.4	.....
Retained on No. 200 sieve	28.8	23.4	.....
Specific gravity	3.12	2.95	2.79
Accelerated tests, American Society for Testing Materials, 5 hours steam.	K	K	Checked and warped.
SO_3	.....	1.34	.....

A. L. JOHNSON (by letter).—The members of the Cement Committee defend the very wide range of values permitted in these specifications on two grounds: Mr. Johnson

First, that they do not know how the cement will be tested; and second, that they do not know the requirements of the engineer.

It seems to the writer as self-evident that it is the duty of the committee to say how the cement shall be tested; and also as self-evident that the engineer wants a first-class cement. If he wants second-class cement he doesn't need any specifications; he can get that without any trouble.

Assuming that he wants a first-class cement, it then appears that there are different kinds of first-class cement, and that a cement which would be first-class for one purpose would not be so good for other purposes. While this may be true to some extent, yet, if you eliminate all cement which, though admirably suited to certain purposes at the beginning, in time shows a de-

Mr. Johnson. crease in strength, there will remain little to differentiate into classes. About the only thing we can ask of a cement is that it shall get hard and stay hard, and the sooner it gets hard the better, so long as it shows later no falling off—"Getting hard" here is used in the sense of acquiring strength. Unfortunately, with our present methods of manufacturing, cement that gets hard quickly is likely to show an ultimate retrogression.

Under the present conditions, therefore, two classes of uses might be made, though in the writer's judgment this would not be necessary. The first would include monumental work, or structures wherein the stress per square inch on the concrete is low. The cement for such work should be sufficiently slow in hardening to run no risk of ultimate deterioration.

The second class would include those structures in which the requirement of strength in the concrete is great at the age of one month. Many reinforced concrete structures are required to carry the specified ultimate load at this age. For such cases the cement would have to harden more quickly and hence come closer probably, to the line beyond which ultimate deterioration might occur. But as a matter of fact you wouldn't want to come closer to this line than would be safe in any case; and that close you might as well come in all cases. So that, after all, there seems to be no necessary differentiation here.

The writer believes, therefore, that the committee could and should describe the qualities of a first-class Portland cement, and tell us how all other grades may be eliminated. This they have not done.

Mr. Humphrey. RICHARD L. HUMPHREY (by letter).—A careful review of Mr. Brown's criticism of the proposed standard specifications for cement fails to reveal definite suggestions as to the manner in which they could be improved.

After twelve years' experience in testing cements, his statement that the purity of a cement is determined from its tensile strength, is a revelation so novel that it cannot be accepted without proof. (From Mr. Brown's remarks the term purity is taken to mean freedom from adulteration.) The purity could no more be established from the results of the tensile strength tests than could the degree of fineness be determined from the tensile strength with sand. It should be noted that fineness and time of setting are

quite as generally used as the accelerated and tension tests, and are important tests which should not be omitted. Mr. Humphrey

In the consideration of a standard specification for cement it should be borne in mind, that about 90 per cent. of the tests are made in small laboratories under less favorable conditions and by less skilled operators, than is the case in the large laboratories, and it is not advisable to fix the requirements for the tensile strength tests too high because such laboratories would probably experience difficulty in passing cements of the highest quality.

In the experiments made under the direction of the Committee on Standard Specifications for Cement, by some thirty-two laboratories there were a number of instances where first class-cements failed to meet even the lower limits for tensile strength of the proposed specifications.

It should also be remembered that a number of large of works are being constructed with cement, tested under specifications having lower requirements than those in the proposed specifications, and further, that many engineers of experience question the desirability of high-testing Portland cements, but prefer those giving lower results, and which show a better progressive increase in strength with age.

It should not be forgotten that the question at issue, now, is, "Do the proposed specifications, if rigidly enforced, guard against inferior cements, and will they secure cements of first-class quality suitable for any important work?"

Considering Mr. Brown's objections more specifically it should be observed that he illustrates his remarks by quoting the results of a few tests, an average of five briquettes. Conclusions should be drawn from a large number of tests, all of which should be given.

A cement could be finely ground, low in specific gravity, and So_3, and yet give low results when tested in tension. It would be fair to assume that such a cement was not of first-class quality. On the other hand a cement could be less finely ground, have a high tensile strength (neat and with standard sand), be high in So_3, and not be of first-class quality, the high strength being due to the large percentage of So_3.

In sample No. 1, Mr. Brown fails to state the percentage of So_3, or to give the neat tensile strengths.

Mr. Humphrey

It would be impractical to specify additional chemical requirements because the chemical composition of a cement is variable, depending on the character of the raw materials and the process of manufacture. The committee has prescribed for those compounds which are generally considered to be harmful when present in excesssive proportions, and has guarded against adulterations by inserting in the definition of Portland cement, the phrase which excludes from this class all cements containing foreign material in excess of 3 per cent.

One of the safeguards Mr. Brown would apparently employ to prevent the acceptance of adulterated cement is the test with standard sand. From his remarks it would logically follow that he would accept as the requirements for the tensile strength with standard sand for Portland cement, 200 pounds for 7 days, and 300 pounds for 28 days. Under this specification, sample No. 2 (the blended cement) would fail to meet the requirements for specific gravity and for tensile strength with standard sand, and would not, therefore, pass the specifications as he states.

In drawing up a specification most engineers would take the highest value for their minimum requirements; the lower values being given for the use of less experienced cement inspectors, or for those engineers who prefer lower-testing cements.

It should be noted that of the mills in this country engaged in the manufacture of Portland cement not more than 10 per cent. make an adulterated product which represents probably less than 4 per cent. of the total production of Portland cement.

It seems ridiculous to suggest that an engineer desiring to use a blended cement should purchase the ingredients and blend them on the work. Surely Mr. Brown's experience should be sufficient to teach him the impracticability of such a plan. For, to do this properly, the ingredients should be finely ground together, a process requiring expensive machinery, which would increase the cost of the product beyond what it could be purchased for in the open market. As a matter of fact the majority of the mills producing blended cement sell it as such and for less money than first-class Portland cement.

Mr. Brown remarks, "Contrary to the understanding of many, blends to the extent of 40 per cent. will pass the accelerated test prescribed by the committee with ease." He fails to add,

however, that this is equally true of the "Boiling Test," or that most natural cements (100 per cent. blends) also possess the same property. Besides, cement can be so blended that the tensile strength conditions can be met with as high as 50 per cent. of adulterant, so that merely raising the requirements will not reveal adulterations, while on the other hand it tends to increase the quantity of So_3, by the over-plastering, which results from the effort of the manufacturer to meet the high requirements. Mr. Humphrey

As a final remark concerning blended cement two queries seem pertinent at this point:

If a blended cement makes a tougher mortar and possesses all the qualities required for first-class work, what is the objection to it? And what evidence is there that it is an inferior cement?

As regards the requirements for the tension tests with standard sand, while admitting that under skilled manipulation the Ottawa sand yields higher results than crushed quartz, we should not lose sight of the fact that the Committee on Uniform Tests of Cement has not reached final conclusions as regards the standard sand and has recommended the Ottawa sand for the present only. Should it decide to recommend another sand, the Committee on Standard Specifications might be obliged to change the requirements of the specifications to suit. It is for this reason that it is best to maintain them moderately high until a definite standard is adopted.

Again, if the engineer is fearful of adulterated cement he can station an inspector at the works and see the cement manufactured and packed and seal each package or shipment, thereby ensuring against its use.

As regards the five-hour steam test being a mild one, I hardly think Mr. Brown's experience justifies this statement. I understand Mr. Brown's practice is to place his pats in steam for three hours, and then for five hours in boiling water. Three hours steam is insufficient to develop the unsound qualities. Nor is it fair to compare the results of five hours in boiling water with three hours in steam.

There are a number of serious objections to the "boiling-water" test. In the first place, the degree of the "boiling," is not defined and varies in different laboratories from a gentle boil to an ebullition, so violent as to result in an abrasive action to the pats. Then the character of the water varies in different parts of

Mr. Humphrey. the country, some are slightly acid in reaction, others are quite alkaline. Some water is clear, others carry considerable material in suspension. The apparatus in which these tests are made is rarely cleaned at regular intervals, and continual use results in a concentration of the water, increasing the acidity, alkalinity or turbidity. This produces an abnormal condition, which interferes with the test. The concentrated sediments is kept in suspension by the boiling and coats the surface of the pats, thus obscuring the evidences of unsoundness.

In the steam test, the pat is maintained in a clean pure aqueous vapor at all times, and the test is, in my experience, more reliable, and fully as severe as the usual "boiling test." Certainly the cement which satisfactorily passes five hours in steam and subsequently fails in "boiling water" is not objectionably unsound, and I doubt whether Mr. Brown can cite instances where a cement, which has passed the five-hour steam test but failed in the "boiling-water" test, has proved unsound in actual work.

I am unable to follow Mr. Brown in his argument, that because cement is to be used above ground in dry situations, the accelerated test should be rigidly insisted upon. An unsound cement is just as objectionable below ground as above, and an unsound cement should not be used under any condition.

Concerning the cost of retesting, I think the specifications clearly leave it to the option of the engineer. The clauses relating to this point plainly state that they may be made at the option of the engineer. The conditions under which cement is received and tested are governed by local circumstances which could not be covered in a general specification, and which must ncessarily be left to the judgment of the engineer.

The statement that an engineer could be induced to accept sample No. 2 on satisfactory fineness, time of setting (values not given), tensile strength (sand tests only given), etc., is hardly relevant. An experienced engineer could not be induced to accept a cement low in specific gravity and deficient in sand strength for both the 7 and 28 day tests. An inexperienced engineer might be induced to accept anything.

Replying to Mr. Johnson's criticism, I would state that the Committee on Standard Specifications for Cement have defined how cement should be tested by the adoption of the report of the Committee on Uniform Tests of Cement.

Mr. Humphrey

It should be noted that even under standard methods for testing, the personal equation of the operator plays such an important part, that it is impracticable for two operators to obtain concordant results. Since the experience of the operator plays such an important part, it would be impossible, therefore, to specify a single value for each requirement for tensile strength. Such values would be either too low for experienced operators, or too high for inexperienced operators. By giving a range of values the inexperienced and experienced operators are provided for. The requirements of each engineer will naturally be based upon his experience, and the committee cannot be expected to know just what these requirements should be.

As regards the statement, that cements harden very quickly and then deteriorate, I would state that many first-class Portland cements, thoroughly sound and durable, harden very rapidly, become very brittle at the end of several months, and show, when tested in tension, an apparent loss in strength, the cause being the extreme brittleness resulting from the rapid crystallization. The same cements, when tested in compression, do not show the same deterioration.

It would be unwise to stipulate two classes of cement, the one hardening slowly, the other hardening quickly, since for all first-class engineering work it is essential that cement should attain considerable strength in a very short time. A first-class Portland cement will attain a reasonable degree of strength in a very short time and maintain it.

The high tests, which are obtained from many Portland cements, are due to the presence of sulphate of lime, which is added to regulate the time of setting.

In conclusion, I would add that it does not seem wise to fix the requirements of a new standard specifications too high. It is far more rational to start moderately high and gradually increase the requirements from year to year, as experience indicates the necessity.

The committee admits that the specifications are not perfect; but they are the very best that could be agreed on at the present time, and an inspection of the personnel of the committee will at least convince well-informed engineers of its competency.

It is the intention of the committee to gradually increase the

Mr. Humphrey. requirements as experience directs. The proposed specifications are simply a beginning. In the meantime, no engineer need be fearful of the quality of the material which will pass a rigid inspection under these specifications, for they will secure for him cement of the highest grade suitable for any work.

REPORT OF COMMITTEE E ON PRESERVATIVE COATINGS FOR IRON AND STEEL.

On account of the wide difference of conditions and requirements demanded of preservative coatings, Committee E decided to publish in pamphlet form the individual opinions of its members relative to the best methods of testing preservative coatings.

This compilation of the suggested methods is to be distributed among the paint consumers and producers, and engineers, and also through the columns of the engineering and technical press. The methods are published as received.

It is the earnest wish of the Committee that these methods receive the thoughtful criticism of engineers and paint manufacturers, as well as the members of the Committee itself; for it is only by the hearty co-operation of all interested in this important matter, the protection of iron and steel structures, that rational sets of standard requirements can be evolved to meet the many conditions of service.

It is felt that no one set of standard requirements can be imposed on preservative coatings used to protect steel cars, bridge members, structural steel hidden between plaster and expanded metal on one side and brick or stone curtains on the other, and so on through the widely different conditions and requirements demanded in each special case.

In general, however, the paint film which remains most impervious to water, and is satisfactory in other respects, will probably afford the best protection. In a recent paper on "Paints for Protection of Structural Work,"* it was shown that, other things being equal, the finer the particles of the pigment the better the protection, thus emphasizing the necessity for thoroughly impervious coatings.

A satisfactory test to measure this permeability is of the

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* "Result of an Investigation of Paints for Protection of Structural Work," by Robert Job, *Journal of the Franklin Institute*, February, 1904.

utmost importance. One method suggested among the following schemes dwells at length on this point, and recommends the use of a film of dextrine beneath the paint coating. On immersion in water, if the paint be pervious the dextrine film will be dissolved and the paint will peel.

It is possible that the suggested electric insulating values of the same film, tested when dry, and after soaking in some electrolyte, as sodium chloride, may afford a measure of the absorption of water.

The coating, however, must be impermeable, not only when first applied, but also after exposure. This brings up the vexed question of accelerated tests. These tests aim to give in a short time results comparable to actual service.

The protection afforded by cement coatings, though of recent introduction and limited application, seems worthy of further investigation. At present this coating requires a moist atmosphere while setting, a condition hard to meet in practice. Its action apparently depends not so much on impenetrability to moisture as on the neutralization of carbon dioxide and acid gases, etc. This action is so different from oil paint films that a comparison of these two types of coatings will be difficult. The Committee hopes that this phase of the question will be thoroughly discussed.

The methods subjoined are the individual schemes proposed by the members of Committee E to test the efficiency of preservative coatings for iron and steel.

Criticism and discussion should be sent to Joseph F. Walker, Bridgeport, Pa, the Secretary of this Committee.

Respectfully submitted,

S. S. VOORHEES, *Chairman.*

METHODS PROPOSED FOR TESTING PRESERVATIVE COATINGS FOR IRON AND STEEL.

W. A. Aiken.—As Chairman of the Sub-Committee appointed at the last meeting of the Program Committee on "Preservative Coatings for Iron and Steel," I beg leave to report as follows:

Inquiry from the fifteen other members of Committee "E" for suggestions in the line of experience or theory as to the best methods in their individual opinion, resulted in replies from two-thirds of the members and brought out a very general endorsement of the Chairman's personal views, that "service tests" should be very markedly distinguished from "laboratory tests," and that some arrangement should be made if possible to divide preservative coatings into groups for specific purposes rather than to examine each and every kind with the idea of realizing a panacea.

Examination of the various laboratory tests to which the materials which may be selected should be subjected indicates that those for time of drying, porosity, peeling, cracking, etc., are practically uniform. Many suggestions, more or less elaborate, were offered for what may be designated as "laboratory service tests," namely accelerated tests, bearing somewhat the same relation to actual "field service tests" as does the boiling test for cement to the regular long-time test for that material; very good as a corroborative test, but hardly sufficient of itself for classing the material.

In my opinion too little stress is generally put upon chemical analyses. In all preservative coatings certain essential ingredients should be found, and while certain others may do no harm, certain others may or will. Consequently I should recommend that this matter be taken up in so far as fixing within certain broad limits the percentage of vehicle and pigment, as well as determining the quality of the former, and certain ingredients in the latter, for each class of coating examined.

I should recommend:

1. A series of "field service tests," the more extensive the better, conducted, perhaps, through the co-operation of the rail-

roads and the manufacturers of well-known coatings; the former to furnish the structures to be covered and the labor, the latter the material to be applied under their supervision. A number of bridges, both through and deck, might be painted with different coatings of the same shade and regularly examined. The same thing might be done with a series of trusses in large train sheds; with railroad cars of different classes, such as metal, wooden, coal, refrigerator, etc. In every case the various coatings, such as lead, carbon, graphite, etc., should be applied side by side.

In case the above plan could not be carried out, I should recommend a series of "field service tests" on large metal plates at least 24 inches square and $\frac{3}{8}$ inch thick, to be hung in positions as closely approximating average service conditions as possible; over and under bridges; along sides of trusses; in train sheds; over tracks, etc. These plates should always be in duplicate, the one to be painted as is generally done at construction plants; the other to be properly cleaned and painted in approved manner.

2. A series of "laboratory service tests" on two metal and one glass plate, the two metal plates to be treated as above described for the two field service plates; the glass plate to accentuate, if possible, the necessity of a thoroughly non-absorbent, perfectly clean surface to get best results. The details of these laboratory tests should be so elaborated as to disclose the effects of alternate exposure to moist and dry air, acid and alkali fumes, the sand blast, etc.

3. Chemical determinations of the quality and percentage of vehicle and pigment in each coating subjected to test, as a guide for ascertaining the proper proportions from the results of the "field" and "laboratory" tests.

C. B. DUDLEY.—It is to be confessed, we think, that the test of service is the ultimate test which will prove whether any protective coating is or is not valuable. Experiment as much as we will with exposure tests, and plan them as we will, and continue them as long as we choose, it still remains to actually put the protective material into actual service, and see whether it will give satisfactory results. If a metal structure of any kind is coated with a protective material, and at the end of any designated time it is actually found that the material is not corroded, and is in satisfactory condition, it is evident that such protective material

may be regarded as valuable. If not, the verdict will of course be against it.

But experiments with protective coatings in actual service are extremely difficult to make, and are subject to many vicissitudes. Moreover, they require a long period of time before a conclusion can be reached. If the structure is a permanent one, that is, does not move, the results only apply to the location under which the test is made. If the structure is a movable one, such for example as a steel car, there are very serious difficulties introduced into the test, due to the almost impossibility of watching the car while it is in service, and to the danger of losing track of it before the test is completed. Cars are constantly undergoing repair, a part of which is frequent repainting, and unless some one keeps constant watch over the cars under test, results are frequently lost, due to this cause. Also cars are frequently smashed in wrecks, and in this way tests are lost; so that, taken as a whole, while the test of service is undoubtedly the best and the ultimate one, as already stated, it is only with the greatest possible difficulty that a service test can be obtained.

In view of this difficulty, exposure tests on smaller samples have been proposed. Coat, for example, a number of pieces of metal with the various protective coatings which it is desired to test, and expose them for a period of time. Unfortunately such tests have not a few serious difficulties connected with them. It is undoubted that valuable information can be obtained from exposure tests, but these tests have at least four objections to them: (1) The samples are usually small, and small samples do not quite afford the same opportunity to get the proper amount of coating on them, as if the samples were larger. Moreover, the coating is usually done under more favorable conditions, than apply in actual service. Also, there seems to be a fairly well grounded belief that panel tests, as they are called, are not sufficiently like the actual conditions of service to warrant final conclusions. (2) During exposure tests there is always the uncertainty as to whether something will not happen to the test samples, such for example as the record being lost, or the samples being injured in some way, or somebody not conversant with the conditions interfering with them. We have actually had panel exposure tests within sight of our laboratory, where they were under constant

almost daily observation, mixed up, and some of them lost, due to repairs to buildings, or places where the material was exposed. (3) Exposure tests take a long time, and this long time is not infrequently accompanied with changes in the personnel of those having charge of the test, with a forgetfulness as to exactly what was done with the various samples, and sometimes unfortunately with loss of interest in the test. (4) Probably, however, the most valid criticism of exposure tests on panels or small samples is that the conditions are not those of actual service. The samples are located at one place with a certain exposure. This exposure is not the exposure which structures actually get. Furthermore, the small panels are not under strain, which is characteristic of almost every metal structure in actual service, and whatever deterioration may be due to strains does not appear in the exposure tests. We are not trying to demonstrate or prove that exposure tests are not valuable and do not give some indications at least, which may be of service. But we do believe that in order that exposure tests on panels may be really valuable, they should be much more elaborate, and much more carefully watched, than any exposure tests which we have ever known of heretofore.

In view of the difficulties connected with either service tests or exposure tests of protective coatings, it has occurred to us to attack the problem in a little different way, namely, to ask ourselves what the protective coating is required to exclude from the surface of the metal, and if this can be found, to test protective coatings as to their ability to exclude this objectionable material. It is evident that this brings up the question of the theory of corrosion or rusting of iron and steel, and while it may not be possible at the present time to say the last word on this subject, we cannot help feeling that if a protective coating keeps out water in every form, there will be no corrosion. It is on this thesis that what follows is based. If this is not true, our reasoning and suggestions must be regarded as fallacious. If it is true, we think what follows has some value.

Starting then with the statement that if water can be kept out there will be no corrosion, let us inquire in what forms water may get at the surface. It is obvious that there are two sources from which water may come; first, from the rainfall or other exposure; and second, from condensation of moisture from the atmosphere. The successful protective coating, if we are right,

must exclude from the metal water falling on the surface during the rains or water that condenses when the dew-point is reached.

This brings us to the question whether there is any test which will determine whether water permeates paints or other materials designed to be used as protective coatings. We have spent quite a little time trying to devise a test of this kind. Our first thought was to put on glass or other transparent non-absorbent surface, some substance which would change color when water gets to it, and after the gum holding the material had been dried out thoroughly, coat it with paint or other protective coating, and then put the painted object into water. Experiments with anhydrous sulphate of copper and other materials which change color when water gets to them, proved not very satisfactory. Apparently during the drying of paints of which linseed oil is a constituent, water is formed in the layer itself, due to the chemical action. At least our experiments showed some blueing of the anhydrous sulphate of copper, even before the specimen had been put in water. The most successful results which we have obtained in our attempt to test whether water permeates a layer of paint or other protective coating, have been by using a water solution of dextrine. Dextrine can be completely dissolved in water, so as to give a uniform smooth layer, such as appears for example on the back of a postage stamp. This layer when applied moderately thick has a little tendency to peel when drying. The addition of a little ordinary alcohol seems to overcome this tendency. A good working formula is 20 grammes of dextrine, 40 cubic centimeters of water, and 30 cubic centimeters of alcohol. In spreading, it is desirable to have the layer as thin as convenient, and to allow it to dry out without heat for ten to twenty minutes. In heating it is not desirable to exceed 150° F. Such material applied to a portion of a piece of glass for example, and then dried out thoroughly, using heat if necessary, gives a thin layer on the surface. If now the whole piece of glass is coated with a paint or protective coating, and it is allowed to dry, and followed by another or a third coat if desired, the whole being allowed to dry and harden for a period of time, we have as the result an object which, when plunged in water, gives apparently a very satisfactory test as to whether water gets through the layer. We have made a number of such tests, and have found to our astonishment that almost no paint

containing linseed oil as a constituent, is impervious to water. It is obvious when the coated glass is put into water and allowed to stand, perhaps over night, if water gets througk the layer, it will soften the dextrine and cause the material over it to peel. Moreover, a layer of dextrine prepared as above, is almost completely transparent and invisible on the glass after it is dried. But when water gets to it, there is a little change in appearance, making the spot quite visible. This change in appearance and peeling of the coat of paint is the common result with most paints which we have tried, which contain linseed oil. It has been our custom to put the dextrine on in the form of a spot about 1½ inches in diameter, and we have not a few painted glasses where the dextrine covered spot is bare, the rest of the glass still retaining the paint which was put on. The test is new and we have not yet had opportunity to exploit it as far as we would like. It is obvious the glass must be free from grease when coated with dextrine.

There are still some uncertainties in the tests. For example, it is well known that a linseed oil paint does not reach its final state of oxidation, or the change which we call drying, for quite a period of time. We have not yet made any tests, where the paint layer was allowed to harden for more than ten days or two weeks. It is possible that a longer time before the paint was tested would prove advantageous, and there is considerable indication that such would be the case. There are indications still further that the presence of pigment very greatly helps the linseed oil to resist the penetration of water, and also a good deal of evidence that the fineness of the pigment is a most important element in the water resistance of the layer. Furthermore, the nature of the pigment seems to be an element likewise in the problem.

The query may arise, why is it or how it happens that a layer of paint made with linseed oil should allow water to getthrough it?

It seems almost incredible that an oily substance spread out in a thin layer should not so completely repel water that there would be no permeation of the layer. But it must be remembered that dried linseed oil is no longer an oil. The mass of dried linseed oil, if we may trust Mulder's researches, is a tough leathery sort of material, which does not leave an oily stain when touched, and which is changed chemically from being an oil into a matenal which Mulder calls "Linoxyn." During the drying or the change

of the oil to linoxyn, there seems little doubt but that oxygen is absorbed and carbonic acid at least is given off; but if carbonic acid is given off as fast as it is formed, it must escape, and it must escape not only from the outer surface of the layer of paint, but also deeper down in the layer, and it is believed that this escape of the carbonic acid, it being a gas, leaves apertures in the dried layer, through which apertures the water passes when the material is tested, as has already been described. Whatever the philosophic explanation of the porosity of the layer of dried linseed oil paint may be, if our experiments are to be trusted, this porosity is a universal characteristic at least of the layer two weeks old.

It would perhaps be too strong a statement to make without limitation, but we cannot help feeling that our experiments seem to indicate that it is going to be difficult, not to say impossible, to make a perfectly water-resistant protective coating out of a material which consists largely of linseed oil. Substances brought forward as protective coatings which dry by evaporation of the solvent, seem to offer much more prospect of success.

It will hardly be fitting at this time, and in this state of our knowledge of the case, to discuss methods which have been suggested to make the layer of paint impervious to water, such, for example, as mixing with the paint an oil which does not undergo chemical change, but remains an oil in the paint layer, the philosophy being that finely divided pellicles of oil would help to repel moisture; also the dusting over the paint just before it gets completely dry, with finely divided pigment, the idea being to fill in all the little pores or interstices which may be left as the result of the operation of drying, or again the subjecting the painted object to a temperature sufficiently to soften the layer, so that the pores, if any there be, would close up as is done in the well-known operation of enamelling. Our thought in this whole matter has been, if we had some test that was completely reliable, to tell whether any material suggested or offered as a protective coating did actually prevent water from reaching the metal layer underneath, it would be a decided step forward in our study of this interesting problem. It is not hoped or expected that the test suggested above will be final. At present it is the best test that we know how to suggest, and it is hoped that further study along this line, by anyone interested, may result in either improvements in the test suggested,

or the development of something better. Finally it is not hoped or expected that a test which enables us to say that any given protective coating actually prevents water from reaching the material, will enable us to say that such protective coating will be satisfactory in service. Of course exposure tests to get the influence of the sun, and to study durability under actual conditions, are still essential. But it is believed that no protective coating will be a satisfactory one, that does not keep out water, and that every successful protective coating must pass the test suggested, or some modification of it. If our reasoning is correct, we have got to begin at this point; and if our experiments are to be trusted, the protective coatings at present available are not as valuable as we have been hoping.

N. F. HARRIMAN.—The practice of the Union Pacific Laboratory to determine the relative value of paints, is to make the following tests:

Chemical Analysis.—The paint is subjected to the usual analysis for this material, special attention being given to the nature and fineness of the pigment, the presence of dryers and the purity of the oil. If the results of the chemical examination are such as to justify it, the paint is subjected to service test.

Service Tests.—We use pieces of sheet iron, about twelve inches square, for the exposure test, one-third of the sheet being in the condition just as it came from the mill, *i. e.*, covered with scale; one-third is sand-blasted, and one-third has the scale removed with acid. These sheets are coated with one, two and three coats, respectively, of each paint. During application of the paint, attention is given to the spreading and covering power, and the time required for drying is noted. About twenty-four hours is generally allowed between successive coats.

After noting carefully the physical characteristics of the paint on application, these sheets are hung up in places where it is known that the conditions are especially severe, such as in round-houses, under viaducts, etc., in order to get an accelerated test, under conditions to which the paint will be subjected in actual service on such structures.

Paints to be used on wooden structures are generally exposed merely to the weather. In all cases, the sheets are examined at regular intervals and their condition noted. In all of our paint

tests, an effort is made to subject the paint to the same kind of conditions to which it will be subjected in actual service.

International Acheson Graphite Company.—We have recently made, and almost completed, a series of 10 tests on about 40 paints; 4 of these tests being in the nature of long-time durability tests, the other 6 rapid chemical or physical tests. All tests were made in duplicate on surfaces painted with two coats.

The long-time tests included (1) an exposure test, painted strips of sheet iron being placed on the roof of one of the factory buildings; (2) an evaporation test, in which shallow iron pans were partly filled with tap water and allowed to stand uncovered, the loss due to evaporation being made up from time to time; (3) a weak acid test, which was much the same as that last mentioned, except that a 1 per cent sulphuric acid solution was used instead of water; (4) a brine test, a strong brine solution being allowed to drip slowly upon painted sheet-iron strips arranged one above the other so as to drip from the lower end of one strip on to the upper end of the strip next below.

The accelerated tests consisted in treating the coatings (1) with a 2 per cent solution of sodium hypochlorite;* (2) with nitric acid (specific gravity 1.2); (3) with "red" lubricating oil; in testing permeability and water-repellant properties by placing a few drops of water on the coatings and noting the action and, finally, in testing the hardness of a coating and in making a qualitative analysis of the paint.

As a result of these tests, and of the discussion at the recent meeting of the Committee in Washington, we should recommend that a test for porosity of coatings be included, and we are making a number of experiments for the purpose of devising such a test. The method which at present seems most hopeful is that of applying the paints to polished marble slabs, immersing these in dilute hydrochloric acid for a certain length of time and noting any action on the marble after removing the coating, shown either, qualitatively, by a roughening of the polished surfaces or, quantitatively, by the loss of weight of the slabs.

As regards the tests proposed by Mr. Sabin for determining

* This test was extremely severe, but was introduced as a help in meeting a demand for a good protective coating within bleaching powder chambers.

the insulating power and porosity of a coating by subjecting it to a high voltage both when dry and after soaking in water, it seems to us that the nature of the pigment used, as well as that of the vehicle, would so largely influence such tests as to make comparative porosity determinations impracticable.

The service tests proposed in the Committee's last report seem to us as thorough as could be desired.

ROBERT JOB.—In making comparisons with service value results we have found the plan of alternate wet and dry exposure gives rather better data than any other test. The test can be applied with sheet-iron saucers and ordinary evaporation as given in the report of Committee "E" for 1903, or sheet-iron panels, say 5 by 8 inches, may be coated with the material and after thorough drying, immersed each night in water slightly acid, to simulate conditions of coal-car trucks, and exposed to the sun during each day. The paints which have given best service with us have stood this test well. In addition to this we have found that the test of the dried coating with water often gives valuable indications.

By taking a given composition,—say pure linseed oil and inert material,—one can determine by simple tests, such as fineness, etc., whether good results may be expected in service, and a definite standard of quality can be readily maintained. But in the general testing of paints of other composition we at present feel obliged to depend largely upon the longer time exposure tests such as those mentioned above.

Our usual plan is to coat sheet-iron and glass slips, to test these as above described, and at the same time to determine the composition for general information.

JOSEPH DIXON CRUCIBLE COMPANY, REPRESENTED BY MALCOLM MCNAUGHTON.—In outlining a test scheme for protective paints, the following points are to be considered: cost, application, drying, adhesion, elasticity, porosity, resistance to mechanical injury, permanency.

1. *Cost.* This point may or may not be included in a scheme for testing paints. It is properly included when the test is made by the person who is directly interested in the economic side of the question, and may properly be left out by him who has to determine only the value of the paint as a protective coating.

2. *Application.* This bears on the facility with which the

coat may be applied, whether it may be properly applied over other and different coatings, whether it may be applied at all ordinary temperatures, and whether or not any special treatment of the surfaces is required. Knowledge on these points is only to be had by actual trials.

3. *Drying.* Continued observation during an actual trial will give all the information necessary on this point. But it is necessary that observations be made up to the time that the paints are actually hard and dry, because it may happen that one paint may begin to dry on the outside more rapidly than another which may finally pass it and become dry first.

4. *Adhesion.* This is a most important point, it being self-evident that any paint to protect must stay in place. Relative adhesion, when decidedly unlike, may be detected when the paints are fresh by simply peeling off at the point of a chisel. But adhesion must persist throughout the life of the paint, so that it becomes necessary to test the paint films after having given them somewhat the effect of age. Probably as fair a way as any, to secure this effect, is to subject plates of painted iron or tin to repeated alternations of heat and moisture. Tests for adhesion should be made before any others, as a paint coat which lacks this quality, when new, should be immediately condemned.

5. *Elasticity.* This quality enables a paint film to accommodate itself to its base during changes as a result of variations of temperature or form. When we consider the great difference in the coefficient of expansion between the metals and oils, we see that, unless there is a certain degree of elasticity, rupture of the paint film must occur. Films of the paint, detached from their support, are best for determining relative elasticity. The simple test of bending is enough to give information where the difference in elasticity is enough to be of importance.

6. *Porosity.* Since iron does not rust except in the presence of moisture, it is important that the protecting film of paint should be non-porous in the highest degree, without the sacrifice of other desirable qualities. This is a test which should be applied when the paint is in its most perfect condition as a protecting film. It is not correct to test by repeated evaporations of water in a painted dish, because the deterioration of the paint by these repeated evaporations is also involved. The method in which postage

stamps painted on glass, covered with a couple of coats of paint, and when dry, immersed in water, seems good. This may not be exactly correct in its technical aspect, but should give approximately correct results when made for comparative purposes.

7. *Resistance to Mechanical Injury.* Tests to determine this need be made only in special instances where conditions are such that protective coverings may fail from this course. Where such a test is advisable, it is easily made by allowing a stream of sharp sand to flow over the painted surfaces from a hopper, the sand being returned from time to time. The test is easily made more or less severe by varying the height of fall and angle at which the stream strikes the plate.

8. *Permanency.* Protective coatings may be assured as quickly reaching their condition of greatest efficiency. We may consider that when a paint has become what we call dry, it has reached that condition. From that point of greatest efficiency there is a gradual, more or less rapid progression toward ultimate failure. The paint in which this progression is slowest is to be taken as the most permanent. The value of this function must be determined entirely separate from the determinations of the other qualities, and the test should be so conducted as to bring about a slow change, rather than to destroy. The test should be made with especial reference to the conditions under which the paint is to be used. The test should be made with paint films which have been detached from their support. They should be of sufficient thickness, not less than two coats, and probably three would be better. They may be prepared on thin zinc plates, the zinc being dissolved off by dilute sulphuric acid, or they may be prepared on cardboard covered with a paste of dextrine. When dry the whole is immersed in water and the support soaked until it may be separated from the film. Films of various paints to be compared are subjected to the same set of conditions and their relative action observed.

It is much easier to detect changes in films separated in this way than when attached to their supports.

The foregoing tests, while simple, and probably capable of much improvement, are sufficient to give considerable information when made carefully for comparative purposes, yet at the same time they do not give exact values. Under any one test in question,

it will be easy to show that one paint is better than another, but not so easy to show just how much better. Judgment in this matter can only come with experience. It is to be supposed that any test of paints is for the purpose of selecting the one most suitable for some set of actual conditions, and that these actual conditions indicate the relative importance of the tests to be made.

The rate of drying, resistance to mechanical injury, porosity, adhesion, etc., may each in turn be the feature of greatest importance. It would certainly be an absurdity to lay much stress on relative porosity of a coating which is to be applied to bridges in Arizona, or to pay much attention to the matter of elasticity in a paint for ironwork in a damp subcellar.

Unfortunately, no paint has yet been discovered which possesses preeminently all the qualities needed for iron and steel protection, so it becomes necessary for us, if we hope to get best results, to determine in some way what particular product is at least as good as any other for the case in hand. Our tests may not always indicate the very best, but they will undoubtedly put aside the very worst, and this result alone will be a great gain. It seems to be entirely within the scope of this committee, in addition to suggesting methods of making tests, to suggest also a scheme for combining the values obtained by such tests, into an equation, the solution of which will give relative values in particular cases. For instance, the efficiency of a coating may be represented by an equation where one side consists of the sum of the values for the various functions previously determined by experiment, each multiplied by a factor which represents its particular importance in any specified case. Thus in different cases we may take the factors as follows:

Cost 1	Cost 1	Cost 1
Application 1	Application ... 1	Application ... 1
Drying 4	Drying 1	Drying 1
Adhesion 2	Adhesion..... 1	Adhesion..... 1
Elasticity 1	Elasticity 1	Elasticity 1
Porosity 2	Porosity 1	Poro ity 10
Resistance to Mechanical Injury 3	Resistance to Mechanical Injury 1	Resistance to Mechanical Injury 1
Permanency..... 2	Permanency ... 6	Permanency ... 1

The first set might be used in testing paints for steel cars, the second for highway bridges, and the third for ironwork in loca-

tions subjected to steam and acid vapors. Such a scheme will have its limitations and variations due to the personal equation of the man operating it, but eventually there would come a certain degree of standardization. These suggestions are presented with the idea of showing the advisability of a scheme which will necessitate the consideration of all the points involved.

With regard to time tests, not much need be said except that the pieces to be exposed should have at least 2 square feet of area on each side, and should have two coats, the second applied only when the first is dry. The second coat should be dry before exposure occurs, and the exposure should be average conditions it is desired to protect against. The test piece should consist of vertical and horizontal parts, the latter to serve as a resting place for water, cinders, dust, etc. Where such pieces have been examined from time to time, such places should be covered by paint to prevent extension of corrosion from the damaged surfaces. This patching-up paint should be of a different color than the paint which is being tested, to avoid any confusion.

S. B. NEWBERRY.—It is difficult for me to suggest a scheme for testing Portland cement as a protective coating for iron and steel, since the methods of using it for this purpose have not yet been developed. After carefully reading the outline of tests suggested by Committee "E," however, I think there is no reason why cement should not be submitted to the same tests as other paints, so far as these are found to be applicable. Cement coatings should, however, be kept in *moist air* at least 24 hours after being applied. Whether this will prove practicable on a working scale must be determined by experience.

For these experiments cement in extremely fine state of division will be necessary. We have facilities for furnishing such cement, prepared from our regular product by air separation, and could ship a barrel or so for experiment at any time. The cement should be mixed with water to about the consistency of ordinary oil paint, and kept thoroughly stirred while being applied.

I would suggest also experiments with cement with the addition of calcium chloride to the amount of 5 and 10 per cent of the weight of the cement, having found by experiment that this aids greatly in producing a thorough set of the cement before drying takes place.

Patterson-Sargent Company, represented by W. A. Polk.—"In experimental science, two methods of progress are observed; first, in actual practice certain methods are adopted because they are found to be the most advantageous and useful, though we cannot explain why it is so—*i. e.*, practice outstrips theory. Again, as a result of experimental investigation, certain facts are discovered which explain why the practical methods just alluded to are the best, and this in turn suggests further improvements in our practice—*i. e.*, theory outstrips practice and enlarges its domain. This is what the laboratory does for the paint business."

The writer has had some experience in observing tests of paint made by covering plates of sheet iron and exposing these in places where the conditions were particularly severe. For instance, in making a test of paint for the protection of the steel on the interior of a train shed, such painted plates would be hung in positions where they would receive not only the gases and fumes from the locomotives, but they would be hung directly over the smokestacks in such a way that the blast of cinders and the direct contact of sulphurous gases would affect the painted surface to a degree which would seldom occur in practice.

The adherents of this system of making tests naturally ask, is not the paint subjected to the same conditions and is it not a truly comparative test? Such a test would be truly comparative but that is not what is desired, if I understand the scope of the subject in hand. Surely, if a train shed is to be protected from gases, it is to be protected as a whole, and no particular spot is to be especially singled out for protection. Whilst such places are to be found in all train sheds, they must have special treatment. In other words, the diagnosis of each case must be based on the conditions of that particular structure.

In respect to the preservation of bridges, many tests have been made in which none of the coatings were applied directly to the surface of the bridge in question; but plates were painted and suspended beneath the structure. The same objection applies to this sort of test as to the one referred to above. On a railroad an entire bridge should be painted with a coating of one character, whilst half a dozen others on the same division, subject to the same conditions, should each be painted with a coating of a different char-

acter. Practical results could be obtained in this way which would be far more instructive than those obtained from a number of plates hung under the same bridge. The question may be asked: Is it possible to find two bridges alike in respect to the condition of the surface to be painted? Theoretically no, but practically any two surfaces may be made essentially identical by thorough cleaning.

To go back four years, to the tests made on the One Hundred and Fifty-fifth street viaduct over the Manhattan Elevated Railroad, under the supervision of the Department of Public Works, for the purpose of determining the relative merits of a number of protective coatings, an expense of several thousand dollars was incurred in cleaning the surface of the bridge by means of the sand-blast. In this case a practical as well as a theoretical demonstration was made of the possibility of cleaning a surface perfectly. The surfaces to be painted were of sufficient size to ensure results of practical value. These results are matters of record, but the point that the writer would especially accentuate is that this test was made in a thoroughly practical manner.

The preservation of steel cars is a question requiring careful study. The preparation of the cars for painting is obviously of prime importance. An experience will serve to show to what extent this point should be considered. In making an observation recently the writer noticed that the plates of a new steel car were covered with oil which had been used on the rivet holes. This oil had spread over the surface of the car in large spots. The writer instructed the painters to remove the grease entirely from the surface, but before these instructions had been given the men had painted a part of the car without removing the grease. On the following day, after the entire car had been painted, it was found that the coating was entirely dry except on the first section from which the grease had not been removed. The paint on this section was perfectly wet; that is to say, it was in the same condition as when first applied. In order to expedite the completion ot the car, the men were instructed to wipe off both the wet paint and the grease which had caused the trouble. Where the grease remained, both it and the paint could be wiped off, but from contiguous spots where no grease existed the paint was hard and clung so firmly to the steel surface that it was removed with difficulty by the use of a knife.

Another matter of importance in this connection is the removal of mill-scale and rust. The painting of steel cars offers an opportunity of painting under precisely the same conditions if each car be cleaned alike. Naturally the conditions of exposure vary to some extent, but a record could be kept of certain cars and by inspection from time to time instructive results might be obtained. Cars might be chosen which remain continually on the same railroad, for example, cars carrying coal from the mines to tidewater.

Much might be said concerning tests of protective coatings in respect to ships, but I believe this should be regarded as a distinct field and receive separate treatment.

It is frequently impossible to get the best results from the use of a good protective coating, owing to the lack of practical knowledge of painting by the inspector, both in the shop and field work. If a good job of painting is desired, a good paint must be used, but *good paint will not apply itself*. The best paint ever made will blister, peel, flake and give all sorts of trouble if it is not properly applied. The principal causes of trouble are as follows:

1. *Moisture.* Paint will blister and peel, if the surface to be painted contains moisture, for paint will not adhere to a damp surface. For this reason, paint should never be applied in wet or freezing weather.

2. *Thickness of Coat.* Paint will blister and peel, if it is applied too thickly. *Rub it out well.* A thin coat of paint will wear better than a thick one. There is perhaps more trouble from this cause than any other. A good brush must be used to rub paint properly.

3. *Bad Primer.* Paint will blister and peel, if the primer is not right. Many seem to think that anything is good enough for a primer. This is a serious mistake, as the primer is the foundation, and, therefore, the most important coat. A surface well primed almost always means a surface well painted. A different shade from the finishing coat should be used for the primer, so as to aid inspection.

4. *Time for Hardening.* Give each coat time to harden before applying the next, as a second coat will not adhere to the priming coat if the priming coat is not thoroughly dry when the second or finishing coat is applied.

5. *Workmanship.* Employ skilled labor in making tests, as it requires experience and good judgment to apply paint right. The inspector should be instructed in certain everyday practical points to be observed in the application of any protective coating; for example, that the surface is free from grease; that the paint is thoroughly rubbed out, and not flowed on like white-wash; that a stiff round brush is used, which carries more paint and enables tt to be well brushed out. Careful inspection will always assist ihe engineer in securing a satisfactory protective coating.

In designing a series of tests to determine the efficiency of protective coatings it should be clearly understood for what purpose the paint is intended, and such tests should be applied as will determine its fitness for the special purpose in view. Should our Committee succeed in this respect its work will be of great value, but, to quote the opinion of a well-known chemist, "It would be unfortunate if it narrows itself down to the idea that a few laboratory tests can be applied to any paint, and its fitness for any purpose thus determined. The rational solution of the paint, or, rather, the painting problem, seems to be to have the case prescribed for by some one familiar with protective materials, and the question of whether the paint shall be thin or thick, or what shall be the composition thereof, will have to depend upon the conditions to be met. Familiarity with the various paints offered for sale is perhaps of more value than a series of tests in a small way, and the conditions of service are now pretty well known, so that a knowledge of the composition of the material offered is nearly always sufficient criteria upon which to base an intelligent opinion."

A. H. SABIN.—Comparative tests for protective coatings for structural steel must be time-tests under such conditions as are to be met in actual practice. I do not think that any so-called accelerated tests which have yet been proposed are of any value, but on the contrary are misleading. The fact is that the intelligent use of such material requires that for any given use a coating shall be selected which is especially appropriate for that particular kind of service; and that it shall be used in such a way as to prolong its efficiency as much as possible. On the other hand, the person who plans for an accelerated test devises conditions which will destroy the coating as rapidly as possible without entirely obliterating the differences between the various preparations used.

These conditions must be not only abnormal, but unnatural; and the end sought is exactly the opposite of that desired in practice. Even when the action of a single agent is concerned, it is impossible to prove that an increase of intensity is similar to a prolongation of action; in fact, a little reflection shows this to be in its nature improbable. For example, let us consider the effect of temperature; it has been proposed to learn this by exposing the object for a short time to an increased heat. But at once we encounter difficulties; thus, wooden beams exist in a roof a thousand years olds and wood is found in Egyptian tombs two or three thousand yearn old; but if we heat a piece of wood to 400° F. for a short time it iy destroyed. Again, some varnishes or paints are by a certain rather high temperature fused into an enamel, and their durability and protective effect greatly increased. Thus it appears that the effect of heat is uncertain and incalculable. The same is known to be true of some chemical agents, and is perhaps true of all. I conclude, then, from these and other reasons (as well as from experience and observation), that accelerated tests are misleading and irrational.

Certain so-called exposure tests are also of this nature. There are many places (such as the smoke-jacks in a round-house) where experience has shown that paint does not afford any protection; obviously these are not places to put paint. It is a waste of time and money to paint such places; it is as useless to expect paint to be of value as it would be to expect it to increase the strength of a bar of metal. No exposure test is of value which is not conducted under as favorable conditions, and as nearly as possible the same conditions, as those which will be met in practice.

These imply that the paint shall be carefully and skilfully applied to a steel surface. The question now arises, shall this surface be specially cleaned, as by pickling or sand-blasting, or shall it be covered with mill-scale, or with a more or less thick coating of rust? Some users of paint say that as it is impossible for them to clean the metal thoroughly, and as they wish to know what is the best paint for their conditions, they want a test on rusty iron; they are looking for a coating which will arrest or retard rust which is already well under way. This does not to me seem the proper function of paint; but we may let that pass; if the consumer thinks that is what he wants, and the supply man wants

the consumer's money, it is probable that they will try to find some common ground; still, I do not conceive it to be the business of this Society to encourage unreasonable and unjustifiable expectations. But leaving that view of the matter out, what will be the result of such tests? It was said by Smeaton, over a hundred years ago, that if rust had started it was impossible to stop it by paint; nearly every expert since his time has repeated this conclusion; and while some engineers will tell of great success in using paint on rusty iron, I never saw a paint manufacturer who believed in it. The most immediate difficulty is the lack of uniformity in results. It is impossible to get two rusty plates which are alike; and not only are there different thicknesses, but different kinds of oxides, holding varying amounts of moisture. The steel itself is not a homogeneous substance, and the differences in its composition are emphasized and made more important by the varying conditions of rusting. If we would gain uniformity it is only by avoidance of rust. This is the most immediate argument against the use of rusty plates. I do not believe the experiments repeated with the same paints on rusty plates will ever give similar results; and I think it is common experience that irrational results of tests are either traceable to or are attributed to differences in the surfaces to which the paints were applied, more often than to any or all other causes. I know that so far as I am concerned, I would never take any interest or attach the slightest importance, to paint tests made on rusty surfaces.

If the tests are to be made on clean plates, they may be cleaned either by the sand-blast or by pickling. The former is a very perfect method, but not always available. Pickling with acid is easily done and requires no special apparatus. If the plates are greasy, they should first be put in a hot 10 per cent solution of caustic soda for a few minutes, then well rinsed with hot water; they are then put into a hot solution of sulphuric acid, the usual strength of which is 10 per cent, but may be as high as 25 or 28 per cent. They are left in this until a clean surface is obtained; this may take from five minutes to an hour or more, according to the condition of the acid bath. They are then washed; the common way is to dip them in hot (preferably boiling) water, then in hot 10 per cent carbonate of soda solution, then again in boiling water (if this is used for many plates a second

rinsing in hot water is desirable), then they are dried in a hot oven. Or they may be taken from the acid and plunged at once into boiling milk of lime, and after a few minutes rinsed in hot lime-water, then dried in an oven, and when dry thoroughly brushed to remove the adherent lime. Or, they may be taken from the acid and washed by a jet of water impinging on them with a velocity due to a pressure of at least a hundred pounds per square inch, and then dried in the oven. Having cleaned them, the utmost care must be taken to keep them clean. They should be handled only by their edges, and kept in a box the bottom of which is thickly covered with dry caustic lime, until the paint is quite ready for application, when the first coat must be applied as rapidly as possible, in a dry warm room, to both sides of the plate.

Both the size and thickness of the plate should be considerable. My own tests have been made on 12 by 20 inch plates, $\frac{1}{8}$ inch thick; larger ones would be better. They should be of that class of steel plates known as "pickled and cold-rolled," having been pickled at the mills before the final rolling. Care should be taken to have all the plates from the same lot of steel; even then I do not believe they will all be alike. Each plate should have a hole, about $\frac{3}{8}$ or $\frac{1}{2}$ inch, about an inch from the middle of each end, to hang them by; and a number should be stamped on the plate in some convenient place; the centre is as good as any. In addition to the stamped number I have always marked the plate on the edge with a series of saw-cuts; thus, plate 176 would have, first, a single cut, then a clear space of an inch (to the right), then seven cuts, then a clear space, then six cuts. These marks can never be obliterated by rust, and are easily found. All this, of course, would be done before pickling, so as to avoid fouling and rusting the plate.

Paint is always thin on the edge of a plate; and the border of a plate, for at least an inch back from the edge, should not be counted in a paint test; but as rust always spreads from the edge in a prolonged exposure, I would apply a striping coat along this margin between the first and second coats and also another after the second coat; and even then I think it would be the best way to have each plate set in a wooden frame, such as are put on slates for school-children, after the painting is completed. This is to provide against accidents; an accident destroys the value of all previous work.

Each coat should be as thick as will lie evenly, and should be given time to dry before another coat is applied; I should say a month in a warm dry room; while drying, the plate should be hung away from the wall; I usually hang them to the ceiling.

At certain designated spots, say two inches from the edge and opposite the middle of each longer edge, also halfway from that point to each end (six spots in all) the thickness of each plate should be measured by a micrometer caliper immediately before painting, and again after painting and drying before exposure; this shows the thickness of the film. At stated intervals this measurement should be repeated. It appears to me that it might prove a valuable plan to have a duplicate set of plates, and from time to time determine the insulating power of the coating; not that I would care for the absolute insulating power, for some paints naturally are better conductors than others, but most paints are insulators, and the resistance to current indicates in such cases a non-porous coating; and if they become porous by exposure or age the electrical test should show it. These tests would naturally be made successively on different parts of the same plate, not rupturing the coating at any one time except in one place. I do not think that such an experiment has ever been made; but if it would show the porosity of the coating at different periods it would be of the highest interest.

Not less than two coats of paint should ever be used in practice, because all paint is porous, and we overcome this defect in a measure by successive coats; hence I would value tests made with two or more coats; but in my own practice I find it instructive to expose a single coat; this is, however, done by me in testing varnishes rather than protective coatings in general. I find that an exposure of a single coat for a period of three to six months results in a sensible deterioration; these exposures are made on the south wall or the roof, where the conditions are very severe. I have never tried any coating which will not begin to show deterioration in six months; and it may be that tests of this kind will prove of some value. Any such tests should be made with as much care and concurrently with other long-time tests of the same material used in two or more coats.

As to the places where exposures are to be made, it seems to

me that a series of plates should be exposed on the roof of a building, rigidly attached to a framework, so that the sun, wind and rain can get at all equally, within two or three hundred feet of the shore of a body of sea-water; another set similarly exposed in the country, away from the coast; perhaps a set near the shore of one of the great lakes; and a set should be placed on the roof of a not very high building in or adjacent to a railroad yard, where it will receive the gases from engines. I would not make exposures on the tops of railway bridges, because no two plates can possibly have the same exposure; and the same is true of train sheds, unless the cases containing the frames can be so placed that it seems certain the exposures will be uniform.

G. W. Thompson.—Protective coatings should be selected or designed by the architect or engineer according to the conditions to which the coating is to be subjected, and with such knowledge of the qualities of the coating as will enable him to satisfy himself intelligently as to the merits of the coat to be applied.

A protective coating protects in proportion to its impermeability, its hardness and its elasticity. It should be as impermeable as possible to moisture, which is the principal factor in the corrosion of iron. Hardness and elasticity are, to a certain extent, the reverse of each other—the hard paint being usually inelastic and the soft paint elastic. Generally speaking, a paint should have the maximum hardness consistent with the elasticity required by the conditions to which it is subjected. With extreme variations of temperature, such as occur on bridges, great elasticity is required; while, with the steel framing of buildings and underground work subjected to little variation in temperature, elasticity can safely be sacrificed to hardness. Tests on permeability, hardness and elasticity of protective coatings should be applied wherever practicable.

Generally speaking, the impermeability of a coating is proportional to its thickness. The architect or engineer should, therefore, know the approximate thickness of a coating or coatings when applied. The surface covered is inversely proportional in area to the thickness of the coat left on the surface. All protective coatings should be brushed out as thoroughly as possible, as, otherwise, there will be sagging and settling out of pigment, if pigment is present, this settling being sometimes away from the

surface painted, as on the under side of I beams. The architect and engineer, by knowing the spreading power, and from this the average thickness of the coat applied, can judge whether the additional cost in labor in the application of extra coats is warranted in the case of protective coatings of high spreading power; they should continually bear in mind that high spreading capacity is not in itself a good quality in protective coatings for the reason given—to wit, that a paint having a high spreading capacity gives a comparatively thin coat on each application. One gallon of paint spread over a perfectly smooth surface so that it covers 800 square feet of surface would have a thickness of 1-500 inch. In the case of a protective coating that is spread twice as far as this in each coat, the number of coats should be doubled to obtain equal protective power, provided other things are equal.

The architect or engineer should also know what proportion of the paint is volatile, as that adds nothing to the thickness of the protective coating and, in this particular, nothing to its protective value.

If the protective coating contains solid pigments—if it is a paint, in other words—the architect or engineer should know in what proportion the pigment is present both by weight and by volume. It may be considered as well established that in linseed-oil paints the greater the per cent by volume of pigment, the greater will be the impermeability of the protective coating; to this extent, at least, the pigment protects the vehicle.

It should be borne in mind, however, that hardness and elasticity of paints are proportional to the per cent of pigment and non-volatile vehicle present. The architect or engineer should, it is believed by some, specify a high per cent of pigment where a hard paint is desired, and a high per cent of non-volatile vehicle where a paint of great elasticity is desired. A paint high in pigment has a low spreading capacity; therefore, where great elasticity is desired, it can be accomplished by increasing the per cent of non-volatile vehicle and securing proper thickness by an increased number of coats. The spreading capacity of a paint is reduced by an increase in the per cent of pigment present; in other words, the greater the per cent by volume of pigment, the greater will be thickness of the applied coat. The fineness of the pigment should be such that there shall be no tendency to run or "weep" when the paint is properly spread out.

The architect or engineer should possess a reasonable knowledge of the chemical composition of all protective coatings for iron and steel. He should know:

(*a*) Whether there is present in the paint any constituent that would, on oxidation, form mineral acids. The analysis should show whether the vehicle contains sulphur or chlorine, as it is believed by some that such vehicles by decomposition and oxidation cause the formation of corrosive mineral acids.

(*b*) Whether the vehicle contains lead or manganese, or both. It is believed by some that manganese makes the vehicle dry too rapidly (as compared with lead alone) and to continue drying until the elasticity of the paint is destroyed.

(*c*) Whether the vehicle contains non-volatile, unsaponifiable matter (usually heavy mineral oil), for, if it does, it is believed that as the drying oil dries it separates from this unsaponifiable matter and an unhomogeneous coating is obtained. It is also believed that heavy mineral oil, if present, causes the paint coating to lose its (tensile) strength on drying and to alligator, leaving large cracks through which corroding gases can reach the metal—also weakening the hold of the paint to the metal surface to which it was applied.

(*d*) Whether the pigment contains substances that are electrical conductors, as these substances, if present, reduce the insulating capacity of the protective coating and, consequently, under some conditions, it is believed, may favor the destruction of the metal by electrolysis.

(*e*) Whether the paint contains electrolytes, as, under some conditions, it is believed that the presence of electrolytes favors destruction of the metal by electrolysis. Sulphate of lime is an electrolyte, for instance.

(*f*) Whether the pigment is basic in its character. It is generally accepted that the tendency for iron and steel to corrode is lessened by the presence of alkalies. It is believed by some that this protective quality is possessed by pigments of a basic nature, such as metallic oxides that are capable of combining with the carbonic acid, etc., in the air and thus preventing its reaching the metal to be protected.

(*g*) He should know, finally, within reasonable limits, the other constituents of which the paint is composed, to ensure com-

pliance with specifications and also to explain such peculiarities, good or bad, which the protective coating may exhibit.

To summarize:

1. General tests should be applied to protective coatings, wherever practicable, to show their specific impermeability, hardness and elasticity. Standard methods for making these tests have not yet been formulated, but, when their importance is fully realized, generally acceptable methods will doubtless be proposed.

2. Painting tests should be made showing the spreading capacity and average thickness of coatings.

3. The per cent of pigment and non-volatile vehicle should be determined by weight and by volume (calculated from the per cent by weight and the specific gravity).

4. The per cent of volatile thinner should be determined—also its nature.

5. The fineness of the pigment should be tested; this can be done in many cases by determining the per cent coarser than No. 19 silk cloth.

6. Chemical analysis should show the composition of the vehicle and pigment, within reasonable limits.

J. F. WALKER.—The question of comparative testing of protective coatings has been to me a most interesting subject, but one in which I have always been plunged in chaos on account of the varying results which I have obtained. The so-called accelerated tests are to my mind of little value and to a great extent misleading. Usually, in painting a structure of any kind for test, the work is done under the most favorable circumstances in an endeavor to get the best possible results. In an accelerated test the most abnormal conditions are selected.

In an endeavor to test a coating six points are to be considered, viz: Drying, method of application, adhesion, elasticity, porosity, chemical analysis.

1. *Drying.* This is an important feature and the simplest of all tests, consisting only of applying the paint to a surface and noting the time required before a second coat can be applied. A paint for general purposes should require, I think, not longer than from 8 to 10 hours to set sufficiently for the application of the second coat.

2. *Method of Application.* The method of application I consider a very important element. No matter how good the paint is, if not properly applied the results will be of no value, either in an accelerated or time test. This question of proper application in practice is one which I think the Committee should seriously consider and for which proper recommendations should be made. In applying a paint to a surface, we can readily determine its working qualities, and the range of temperature for which it is adapted.

3. *Adhesion.* Adhesion is a very important factor. A coating that will not adhere to a surface is of no value. This is readily determined by a mere scraping of the paint with a sharp instrument.

4. *Elasticity.* This quality allows the paint to adapt itself to the surface under varying conditions of temperature. The simplest test for this is a scraping of the paint film, noticing whether it peels in long strips or flies off like fine dust.

5. *Porosity.* After all other requirements have been fulfilled, if the paint film is of a porous nature, it is absolutely of no value. Without doubt, this is the most important of all tests, and one concerning which we can as yet get no conclusive result. Numberless tests have been suggested and tried, but with such varying results that little or no light has been thrown on the subject. The tests should be made after the film has been thoroughly aged and hardened. Probably the best is the alternate wet and dry exposure test, using sheet-iron saucers for evaporation.

6. *Chemical Analysis.* After testing a paint for its drying qualities, the engineer should determine the constituents of the coating by a chemical analysis. The results of his analysis will enable him to judge in a measure the probable wearing qualities of the paint.

M. H. Wickhorst.—In making exposure tests of paint samples our practice is to paint pieces of glass, 6 by 8 inches, with one, two and three coats respectively, and expose them on the roof, facing south at an angle of 45° to a horizontal. This we think is about as severe a test as we could make under natural weather conditions.

It would be very desirable if some artificial weathering test could be devised that would be identical in its effects with natural conditions, but we have yet to discover such a test.

THE A. WILHELM COMPANY, REPRESENTED BY C. T. DAVIES. —Where time is limited, we consider the chemical work by far the most important. Much information as to the wearing qualities and intrinsic value of paint can be thus obtained.

We presume, however, that it is not the intention of the Committee to collect data as to chemical methods for analyzing paints, and we shall therefore confine ourselves to methods for making physical tests. If data as to chemical methods for analyzing paint are desired, we shall be pleased to furnish our views as to what we consider the ideal methods.

Physical Tests. Methods that will eliminate all possible errors, atmospheric and local conditions, and influences from surfaces over which the paint is applied, should be used. To accomplish this, where comparative results are desired, we would make all tests on glass, being careful to have the glass thoroughly clean and free from moisture. This will insure a surface that is at all times uniform, and one that will have no chemical or physical action on the paint.

In connection with this test, we would likewise suggest that exposure tests be made on wrought and cast iron, being careful to have the metal thoroughly pickled, cleaned and dry before applying the paint. The results secured in this way, however, we do not consider sufficiently trustworthy for definite conclusions, nor sufficiently accurate for comparative purposes.

The ideal physical tests are those that will produce the same results at all times and in all places, no matter by whom made, and that may be definitely formulated. These may be classified as follows: covering capacity, fineness, fading, general appearance.

1. *Covering Capacity.* This should be expressed in figures, and we would suggest the following method that we have employed with success: Coat the surface with the paint to be tested. If "ready-mixed," use as received; if in paste, or semi-paste form, thin with a fixed amount of oil and the necessary amount of japan to dry. When this coating is dry, stripe with a flat paint of opposite color, say for a black, red, brown or any dark-colored paint, use a standard zinc oxide; and for white, gray, etc., use a standard black. When the flat stripes are dry, cover the surface with a second coat of the paint to be tested. Then take the paint, if black, red, brown, or dark color, and dilute with the standard zinc oxide until the

shade of stripe is matched and the covering can be expressed in terms of zinc oxide. If white, gray, etc., match color with the standard black, and express results in terms of black.

2. *Fineness.* Opinions differ as to whether fineness can be best determined by a test for opacity or a test for ability to hold in suspension. We incline to the latter, and know of no better method of determining this than that suggested by Dr. C. B. Dudley in his specifications for freight-car paint for the Pennsylvania Railroad Company, dated May 23, 1893, from which we quote. "The pigment of the paste must be so fine that after having been separated from the oil and freed from moisture, and then thoroughly mixed again with pure raw linseed oil, which has also been freed from moisture, in the proportion of one part oil to one part pigment by weight it will stand the following test, viz: Place a small amount of the above mixture on one end of a strip of dry glass, set the strip vertical where the temperature is maintained at 70° F., and allow it to remain undisturbed for half an hour. The mixture runs down the glass in a narrow stream, and if the pigment is fine enough, the oil and pigment do not separate for at least an inch down from the top of the test." Excepting, however, when the test is to be made general, and not restricted to one class of paint, the amount of oil used should be inversely proportionate to the gravity of the pigment.

3. *Fading.* Apply two coats of the paint on glass, and when thoroughly dry, cover one-half of the surface with dark paper, protecting same with tin. Expose the glass to the action of the elements and remove the covering from time to time and note the difference in shade.

4. *General Appearance.* By no means least in the order of importance is the general appearance of the finished surface. The paint may be fine, cover well, show very little change of color, pass all chemical tests, and still show an unsatisfactory finish. This may be caused by an improper method of manufacture, an excess of dryer, or the use of an aged paint that has become fatty before applying.

The general appearance can be determined by painting over first coated work, and noting the surface; if not homogeneous and shows a tendency to sag, the paint has either been spoiled in manufacture, or has become fatty with age. If drawn or shriveled, the paint has not been properly applied, or an excess quantity of dryer has been used.

DISCUSSION.

Mr. Sabin.

A. H. SABIN.—I supposed there would be a full written discussion of this subject, and I had hoped that we would have the report of the committee which is, in itself, a very full discussion, in the hands of the Society at this time. The report is not a report as a single paper which all of the members signed or agreed to, because a committee like ours can not be expected to agree to very many things on the paint question, so each member wrote his own report. While we all agree that impermeability to moisture is one of the necessary conditions which must be satisfied by an effective coating, I think that we also agree that no protective coating has that quality to perfection. Oil films, as is well known, are somewhat porous, and we tend to secure freedom from porosity by superimposing one film on another after the lower one is thoroughly dry. I, with some others, think that varnishes are less porous than oils, but even these are somewhat porous and they must be treated in the same way; that is, they must have several successive coatings.

I believe that a coating practically impervious to water may be obtained by applying melted asphaltum or something of that kind, but it is impractical to do this on a large scale. We have at various times heard a great deal about the imperviousness of Portland cement, and some attempts are now in progress to make a protective coating by actually putting Portland cement on the metal. This process offers many difficulties, however, and is in a comparatively early stage of development. I doubt if any one will say that very successful results have been yet reached. I think some of those who have been experimenting with it believe that it is useful; it is a matter of which I personally know but little.

It is, however, not only necessary that a coating shall be impervious to moisture when it is put on, but that it shall be impervious after it has been on for some months. I think that, as a rule, railroad people who have perhaps more systematic painting to do than anybody else, would be reasonably satisfied

if a paint on ordinary bridges would stand three years and be in fairly good condition at the end of that time. Comparatively little paint is in really good condition on steel bridges at the end of three years. Bridges are not usually repainted oftener than once in three years, but many of them are left—in fact, I think, most of them—until they are in pretty bad condition. On the other hand, all paint men who make good, reliable paint can show bridges which have been painted five, six, and seven years, and sometimes ten years, which are in excellent condition. Now, there must be some reason for that. I think that paint men all agree that it is largely due to the proper condition of the metal surface to which the paint is applied, and to the careful and skilful application of a sufficient amount of paint under favorable conditions. Mr. Sabin.

The surface scale should be removed and the metal cleaned, if possible, to the actual metallic iron. This can be done either by pickling, before the structure is erected, or by the sand-blast, and both methods are somewhat expensive. In some cases the sand-blast, at least, is impracticable because it cannot be applied in some places. Last year the Northwestern Railroad undertook to repaint its train shed at Chicago and to clean it first by means of the sand-blast. The passengers made so much complaint about the dust about the station that it had to be given up. It is a matter of common experience that steel which has been cleaned perfectly bright rusts quickly and easily, and the paint must be applied immediately after the cleaning is completed. It is very difficult to get that done. In damp air, and especially by the sea, steel will show a perceptible change in color in two or three hours, and that is a pretty short time for painting. It is known, however, that we sometimes get excellent results without sand-blasting or pickling. The purple scale which is on the iron as it comes from the rolls will in part easily scale off, but some of it adheres with the greatest tenacity. That which can be scaled off should be gotten off at once, but the thin, closely adherent film scale is a good surface to paint on. Most bridges that have shown great durability have been painted on such a surface, for there has not been any appreciable amount of sand-blasting or pickling done in this country, and I think it a good surface to paint on; but rust is not a good surface.

That thin, closely adherent mill-scale is an anhydrous oxide

Mr. Sabin. of iron, practically similar to magnetic oxide; it contains no chemically combined moisture, and from its structure it does not hold uncombined water, which latter is still more objectionable. On the other hand, common rust is not only a hydrated oxide, but it is a spongy substance, which condenses and holds atmospheric moisture mechanically; it contains also other iron salts, the carbonate being probably always present; and other salts may be. Thus, sulphurous acid gas from the use of coal is one of the most common causes of corrosion, and where it is present there will be sulphate of iron in the rust, and sometimes other salts.

The consumer holds that it is not practicable to clean the iron beyond a certain point; and what he wants is paint that can be applied to a rusty surface and give good results, which is out of the question under those conditions.

It seems to me that one of the things which this Society might reasonably investigate would be the relative value of paint sprayed on and paint put on with a brush. Practically there is very little bridge work that is done by means of the spray. It is a much more rapid process than the brush, but there is a good deal of waste of paint in spraying parts like rods and bars, and small pieces in general, because you miss a good deal more than you hit, and the paint floats off in the air and is lost. For that reason it is not more economical than the brush. On practically all structural metal the paint is applied with the brush, but there is a vast difference in the way in which it is applied. The paint should be applied with a good brush. An immense amount of paint on structural work is put on with five-, six-, seven- and eight-inch brushes—flat brushes like whitewash brushes. You get over a lot of surface in that way and it appears that you get a pretty good coating if you do it carefully; but I believe that a round brush or oval brush is the only proper thing to paint with—a good stiff brush with which the paint can be rubbed into the surface of the metal thus getting rid of the air film. There is always a film of air on the surface of the metal and it is necessary to get rid of all air-bubbles and get the paint in contact with the metal as closely as possible. That means work on the part of the men who apply the paint, and that, in turn, means a good foreman and careful inspection. There are several railroads that have gangs of men who do nothing but paint, and who are under the continual supervision of competent

foremen. These men understand that they have got to do their work well and they take pride in it; and on such roads the bridges always look well. Mr. Sabin.

The proper cleaning of the surface and the careful application of the paint, especially the coating that goes on first, are of more importance than the quality of the paint as long as it is fairly good. There are plenty of reasonably good paints on the market. There is of course a difference in paints, and it would be desirable for this Society to work out a scheme, if possible, by which the differences in paints may be discovered. But it would be far more practicable to work out a method of emphasizing the fact that the proper cleaning of the surface of the metal and the proper application of the paint are of primary importance.

I have been talking as though the question of painting applied to structural metal only. As a matter of fact, a hundred times as much paint is put on wood as on metal. People who paint on wood know that if they don't get the surface in reasonably good condition the paint will not stick, and the average quality of painting on wood is vastly better than that of painting on metallic surfaces.

From a chemical standpoint, I think, one difficulty in oil painting is the dryer. I think this should be a low-temperature dryer of which you can not add more than a small percentage and have it produce proper drying effects in the oil. There are two classes of dryers; one which may be called a self-drying dryer, and the other a non-self-drying dryer. The self-drying dryer is a liquid which, if spread out on a glass plate, will dry to a hard film by itself; but there are other dryers which, if spread out by themselves on a glass plate without any mixture of oil, will not dry to a hard film, but will make a greasy film, and that is the kind of dryer which gives the best results in an oil paint. In any paint the percentage of dryer should not be too large. I do not believe that ordinary oil paint or varnish should dry in less than say twelve hours to be dry enough to handle, and I don't think that another coat of paint should be put on in less than a week, and better a couple of weeks. I know that there is a difference of opinion about that, a difference, I may say, which is chiefly between the consumers, or a certain portion of them, and the paint men. Most of the manufacturers object to the use of a very quick-drying

Mr. Sabin.

paint; but some consumers insist that they have got to use it, and that simply means they will use it. I don't believe that permanent results will ever follow from the use of any ordinary paint, such as ordinary oil and varnish paints now in use, unless they are given a good deal of time to dry.

The fact is seldom appreciated that the film of one, two or three coats of paint is only three- or four-thousandths of an inch thick. It is unreasonable to expect a piece of steel which without protection will rust away in five years to a depth of perhaps three-eighths of an inch to be preserved indefinitely by putting on two- or three-thousandths of an inch of paint. The thinness of the paint film is its great weakness, because it is liable to be abraded or scraped off. Often this can not be helped, and for that reason there are many places where I don't think paint is of very much value, or ever can be. Some other means of protecting these places must be devised by covering them with cement or doing something else to protect them. For example, in the case of a low viaduct under which locomotives pass with their smoke-stacks within a few inches of the metal there is a sand-blast action. Such a structure can not be protected with paint. In repainting railroad bridges the paint is sometimes blown off in places before it becomes dry. It is put on as a liquid not supposed to give protection until a dry film is formed, and it is blown away before that. The engineer should be blamed for putting paint in such a place. He should devise something else to put there. When tests are made by putting paint on such places, the results are of absolutely no value to anyone.

The President.

THE PRESIDENT.—I am sure we have all been very much interested in what Dr. Sabin has said. It has been our belief for a long time that the methods of application and the preparation of surfaces had a great deal more to do with the value of paints than is commonly supposed, and we are confident that much of the poor results which we have obtained in the painting of steel cars on the Pennsylvania Railroad have been due to improper application of the paints and to mixing inferior materials with those paints to facilitate their application.

Upon one point I cannot agree with Dr. Sabin, namely, the long time which he asks for between coats. This is simply impracticable for two reasons: First, because in the two weeks which

he wants for painting a car the car will earn ten times as much as The President.
it costs to paint it, and it would be bad policy consequently to hold the car out of service simply for the sake of the paint. But the second reason is still more important, namely, steel cars are made at the rate of one hundred a day, and to allow each car twelve days for painting would require storage room for 1,200 cars, and there is not enough track room around any car works to accommodate such a number of cars. Finally, our own experience does not indicate that rapid drying is detrimental to long life of paint. In regard to the test which we propose, namely, a little spot of dextrine on glass, which is to be painted over, and then the glass put in water to see whether the water gets through and softens the dextrine underneath, causing the paint layer to peel, we would like to say again, as is said in the report, that this test is based on the supposition that if we can keep water away from the surface with a layer of paint it will not corrode. The test is too new to enable us to draw any important conclusion, but we cannot help feeling that it may contain a germ of value. One point I should like to mention, namely, we have struck a difficulty with this test which we do not yet know how to overcome. It looks as though paints could not be applied to any surface with a brush, without leaving air-bubbles in the layer, which air-bubbles do not disappear during drying, and there is an indication that the water gets in through the ruptured air-bubbles. Up to the present time we have discovered no means of overcoming this difficulty, and would be glad of suggestions. As confirmation of the view that air-bubbles are in paint always, and are the means by which water gets through the layer, it may be sufficient to call attention to the fact that corrosion, especially on car sides, is usually spotted, a good deal more in one place than in another. If the layer of paint is equally pervious to water all over, why should not the action be uniform? Possibly there were air-bubbles at the beginning of each of these spots. It has been proposed to overcome the difficulty of air-bubbles by repeated coats, and it is possible that the value of two- or three-coat work may be explained in this way.

In regard to cleaning surfaces, we are hardly able to follow Dr. Sabin, believing that there is no evidence that if everything detachable is removed from a surface, it is essential to have the surface cleaned down to the metal. The old idea that hydrated

The President. oxide of iron parts with a portion of its oxygen, and then takes up more oxygen from the surface, has never appealed to us, and we do not think there is any evidence that this action takes place. Closely adhering rust is all right to paint over, according to our ideas.

One or two points more: Some very satisfactory results in preventing corrosion have been obtained in painting the Jersey City trainshed by Mr. L. H. Barker, the engineer in charge. The method consisted in cleaning the surface of readily detachable material, covering it with a coat of adherent material, paint or asphaltum, or any other adherent material, then covering the surface with paraffine paper, taking pains at the laps, then painting the paraffine paper with paint of the color desired. Two years' experience with this method shows very satisfactory results.

What Dr. Sabin has said in regard to mechanical injury, I am sure none of us can fail to agree with. A coat of paint will not stand the hammer.

Mr. DuComb. W. C. DUCOMB, JR.—In connection with the use of paraffine paper, I should like to say that paraffine itself is sometimes used to preserve the fracture of specimens from rust, especially if the fracture is to be submitted as evidence in court. The paraffine is melted and the broken pieces are covered with it until such time as it is desired to use the pieces, then the paraffine is melted off, leaving the fracture as bright as when the specimen was tested.

Mr. Thompson. G. W. THOMPSON.—This report will prove of very great value, because it brings together the opinions in a true state of the various members of the committee, some of them connected with the manufacturers of paints and some with the use and testing of paints. No matter how just and careful, intelligent and honest any man is, he is more or less biased by his vocation; and when we get opinions from any man, no matter who he is, those opinions must always be taken with a grain of salt. The importance and value of this report will be not so much in the opinions as in the suggestions and statements of fact. Unfortunately, we have more or less of a tendency to generalize too much. If, when we generalize, we state the facts on which our generalization is based, then others can judge whether we are correct or not.

The question of the protection of iron and steel, has in many cases been approached in an entirely wrong attitude. That is

pointed out, I think, in that part of the report in which it is said that no protective coating can be said to be satisfactory under all conditions. There are some conditions where the changes of temperature are great, and what will do in one place will not do in another. So it is of the greatest importance that architects and engineers should understand all about the various paints which they are going to use, and the conditions to which they are to be exposed. Mr. Thompson.

I should like to ask Dr. Dudley in regard to his dextrine test, whether he has thought at all of the possible point of the dextrine being dissolved in the oil of the paint? Linseed oil will, under some conditions, dissolve carbon-hydrates. If dextrine is taken up by the oil it would be natural that the paint when placed in water would allow this dextrine to dissolve and so allow the water to reach the surface underneath.

THE PRESIDENT.—The action of dextrine and oil has not been investigated, at least not by us. The President.

C. N. FORREST.—In regard to air-bubbles, I have noticed that such bubbles are always present when glass is coated with paint, whether this contains pigment of any kind or is on the order of a varnish as Dr. Sabin has described, so the relation between the glass and pigment can hardly influence this fact. Mr. Forrest

A properly made varnish paint will flow more freely than one containing pigment, and when glass is coated with such a paint it will be observed that nearly all of the air-bubbles escape within a few minutes after it is applied.

Varnishes drying by evaporation, rather than by oxidation, possess a further advantage in that the second coat always disturbs the previous one to a slight extent, thus permitting a further and practically complete removal of all bubbles, and the filling of the space occupied by same with more desirable material.

This feature of certain bituminous paints or varnishes doubtless accounts for their superiority as protective coatings for iron or steel, and their greater capacity to resist the action of water than drying oil paints possess in the dextrine test on glass which has been mentioned by our President.

I. H. WOOLSON.—I wish to say a word about the dextrine problem. I haven't had very much experience in the line of testing paints, but I found on making an investigation the same difficulty that Dr. Dudley referred to. I thought I might overcome the Mr. Woolson.

Mr. Woolson. difficulty by using postage stamps pasted on glass, since the paper would protect the dextrine from injury by oil or water. I made only a few experiments, and of those two or three were failures, but the others were successful. I wish to throw out the idea as a possible solution to the difficulty under discussion.

The President. THE PRESIDENT.—We usually put the test glasses in water and let them stand over night. Most paints containing linseed oil will peel the next morning under this test. Some of the bitumen paints will stand forty-eight hours, and but for the doubt as to whether the layer itself is permeated, or whether it is the air-bubbles, we should feel as though we were on firm ground.

Mr. Voorhees. S. S. VOORHEES.—I would state that I had occasion to test some paint recently, and having heard from Dr. Dudley that none of the paints they had tried had been dried for a period of more than a week, I allowed the paint on these panels of glass to dry forty days, and after immersion in water for about a hundred hours, it was shown that the film was impervious and that no peeling occurred. I think that would indicate in this case that the air-bubbles were not the cause of any water getting through.

The President. THE PRESIDENT.—Did you apply two or three coats?

Mr. Voorhees. MR. VOORHEES.—Three.

Mr. Boynton. C. W. BOYNTON.—I should like to ask Dr. Dudley how the glass was prepared and how the paint was applied in his tests.

The President. THE PRESIDENT.—We use a small soft, flat brush, about one and a half inches wide, for painting.

Mr. Boynton. MR. BOYNTON.—My thought was that the air-bubbles might be eliminated by floating glasses.

The President. THE PRESIDENT.—We tried floating glasses and found in the operation of stirring up the paint to get it uniform that some air got into the paint and we still got air-bubbles. It has been proposed to use gelatine capsules instead of glasses, plunging them into the paint, and allowing the excess to run off, with the expectation that the air-bubbles would be carried with it. The gelatine capsules are then put in water, and if the water gets through the layer the capsules will collapse. This method has not yet been tried.

Mr. McNaughton. MALCOLM MCNAUGHTON.—I should like to ask how far you would take this test as an indication of the value of the different paints against corrosion, regardless of other tests, or could it be made regardless of other tests?

THE PRESIDENT.—This is only one of the steps in the study of the problem. If we could get a paint which would stand this test it would be, we think, a decided step forward, and other features could then be studied. The President.

MR. MCNAUGHTON.—I asked that because it occurs to me that in the greatest number of cases in my experience, corrosion follows the destruction of the paint layer, rather than taking place underneath it. Mr. McNaughton

J. J. SHUMAN.—I should like to ask an expression of opinion as to the advisability of using raw oil for the first coating of iron or steel. We have a series of records extending over several years which show that paint applied to the bare metal produces much better results than the same paint applied over boiled oil. Mr. Shuman.

C. M. MILLS.—I would state that I have had a few opportunities to observe the effect of coating bridge material with linseed oil at the shops. I have noticed that the material became rusty after exposure to the weather before erection. In the cases noticed the material had been shipped a long distance, so that it was several weeks after shipment before the material come under my notice. Mr. Mills.

I had no opportunity to ascertain the quality of oil used, and am under the impression that it was raw oil. I do not believe that rusting before the first field coats are applied after erection will be prevented by coating with oil at the shops, unless the time elapsing between the coating with oil and the field-painting is short. It appears to me that the delays incident to the erection of material, by which it remains exposed to the weather, and often under very unfavorable conditions, makes the oiling at the shops, as a rule, injudicious, and that paint would be far preferable.

T. D. LYNCH.—I should like to suggest one point, namely, the detrimental effect that may be due to the acids in the oils. Mr. Lynch.

Experience teaches us that in the protection of electrical apparatus it is essential to have no acid in any oil, paint or varnish where they come in contact with the insulation. It is found that the slightest amount of acid will attack the insulation and copper. In view of this fact, why may we not expect a similar action on iron or steel when acid is present in the coatings? Quite recently I had occasion to coat a large shaft with tallow and white lead. The shaft was polished before coating, thus presenting a surface easily

Mr. Lynch. attacked. After six weeks the coating was removed and, although the shaft had not been removed from a dry building, it was covered with rust over nearly its entire surface.

These are simply suggestions, but it appears to me to be of vital importance to have protective coatings free from acid.

Mr. Wickhorst. MAX. WICKHORST.—I have been listening to the discussion eager for information. In making exposure tests there is a great deal of difficulty in getting results in any sort of reasonable time. I have found that we can hasten results and make pretty fair comparative tests by covering glass with one coat of paint, and then examining its condition with a magnifying glass. Thus we can sometimes get results in a few weeks which would otherwise take as many months, or perhaps extend over two years.

It is my practice in making these tests to expose the sample on the top of a roof at an angle of about forty-five degrees facing south, so as to get the full effect of the sun. I should like to discover some method that will not take even a few weeks. I should like to reduce the time to a few hours, and possibly to make a test of this sort with the films themselves.

Mr Sabin. MR. SABIN.—I wish to add just a word. I think Dr. Dudley and I do not differ substantially in matters of theory. Dr. Dudley says that if you have an impervious film over your coating of oxide that the oxidation will not proceed any further. Of course I agree perfectly with that, but I started out by saying that there is no such thing as an impervious film.

In practice the films are not entirely impervious, and for that reason the surface of the metal must be thoroughly cleaned and prepared, and the oxide must be removed; and I reiterate the assertion, that the vast majority of manufacturers agree in saying that the durability of paint depends more on the preparation of the surface and the application of the material than on the kind of paint, so long as it is good paint.

Dr. Dudley says you have got to use six or eight-hour paint on steel cars. That may be true. But even so, you could use fourteen-day paint perfectly well and get through with it in a day, if the cars were run into a moderately hot oven. I don't believe in high-temperature baking for paints; but ordinary oil paint can be dried in a temperature of 200° to 250° F. in a very few hours. And as to the matter of providing a plant for baking two or three

hundred steel cars, it is a simple thing. If there is enough of such work, the cost of the plant will disappear in a very short time. We have done a great deal of bigger work than that in the way of baking painted steel. Of course it is going to cost a little more at first, but it might be economical in the end. Mr. Sabin.

THE PRESIDENT.—The question of building ovens in which to dry the paint on cars has been discussed, and it looks as though there might be some favorable outcome. Rapidity of drying is not the only thing which would be accomplished by drying in ovens. The President.

JAMES CHRISTIE.—With reference to accelerated tests for paint, I would say that in our works it has been customary for several years, in addition to the usual acid tests, to have an abrasion test, effected by sand falling from a certain height, and noting the time it takes to remove the paint. This may not be new, but I mention it as being useful. We consider it one of the most useful of comparative tests for paint. Mr. Christie.

W. A. AIKEN.—In the case of the rapid transit work, all heavy material, such as roof beams, is always painted, but we have found out by tests on a limited scale, that this is not necessary in our reinforced concrete walls and the reinforced roof of the Brooklyn extension. Where the specifications call for metal therein to be oiled at the shop we do not coat it at all now. Mr. Aiken

A. L. JOHNSON.—I have embedded rods, that had been exposed in a warehouse for two years, and were of course more or less rusty in test specimens, which when broken later showed no signs of rust on the bars or concrete adjacent thereto. Mr. Johnson.

I should not object to any rust on metal unless it were sufficient to produce a scale which would prevent the mortar or cement getting under it. If the steel columns of a building were exposed in a yard for two months before erecting the building, without any protection at all, the scale would be a serious matter; and it should be removed before the columns are concreted. But if it is merely a matter of rust stain which can be wiped off with the finger, I am sure there is not the slightest probability but what the alkalinity of the cement will totally destroy that amount of rust.

Two years ago the Turner building in St. Louis, a steel structure, was taken down to give place to an addition to the building adjoining. The floors were of concrete arches. The beams had been painted with red lead when erected twenty years before. The paint was in a perfect state of preservation.

REPORT OF COMMITTEE G ON THE MAGNETIC TESTING OF IRON AND STEEL.

Since the sixth meeting of the Society and in accordance with the plan outlined at that meeting, your committee has carried on correspondence and conducted research in order to obtain information to serve as a basis for future experimentation.

Correspondence has been had with various commercial and technical laboratories with reference to the methods of testing employed; form of samples used and means of obtaining and method of preparing the same.

It is the opinion of the committee that a comparison of results of tests by a number of investigators in as many laboratories, using different methods, would be of interest and value, and steps have been taken to secure the co-operation of these as follows:—

Obviously the length of time required to test a single specimen in the numerous laboratories throughout the country would be prohibitive, and again each laboratory appears to use a particular method and test piece.

For the guidance of the committee and those who are to co-operate with it, your committee has endeavored to conduct during the year, research bearing upon a standard method of magnetic testing.

As the accuracy of nearly all methods of making magnetic determinations depends upon a comparison with some standard method, it has seemed desirable to exploit to some degree the methods of making absolute determinations.

The most common, and in the hands of a skilled operator, the most reliable method of making absolute determinations of magnetic data is the use of a ballistic galvanometer. It appears also that the Rowland ring method is that most commonly used in connection with the galvanometer.

Experiments have been conducted with a view to obtaining information concerning:—

1. The accuracy of different methods of standardizing the instrument.

2. A comparison of results obtained using specimens of varying size.
3. The possibility of obtaining samples of the same quality from a single casting.
4. A detection of possible errors in the method.

Specimens Used.—For this purpose a flat plate of steel $1\frac{1}{2}$ inches thick and 14 inches in diameter was obtained. This plate was cast horizontally in the mold in order to secure as uniform a density as possible and was used in the unannealed condition. From this plate were cut two sets of four concentric rings, *i. e.* the plate was split in halves and from each half were cut four rings of the same cross-section and the following dimensions:—

Cast Steel Ring No. 1a.		*Cast Steel Ring No. 1b.*	
Outer Diam.	10.18 Cm.	Outer Diam.	10.212 Cm.
Mean Diam	8.58 Cm.	Mean Diam.	8.601 Cm.
Thickness	1.60 Cm.	Thickness	1.616 Cm.
Cr. Sect. Area, ...	2.572 Sq. Cm.	Cr. Sect. Area ...	2.598 Sq. Cm.
Primary turns, ..	154	Primary turns, ..	153
Secondary turns, .	50 to 1.	Secondary turns, .	50 to 1.

Cast Steel Ring No. 2a		*Cast Steel Ring No. 2b.*	
Outer Diam.	16.19 Cm.	Outer Diam.	16.193 Cm.
Mean Diam.	14.59 Cm.	Mean Diam.	14.601 Cm.
Thickness	1.574 Cm.	Thickness	1.590 Cm.
Cr. Sec. Area.....	2.472 Sq. Cm.	Cr. Sec. Area.....	2.537 Sq. Cm.
Primary Turns ..	286	Primary Turns ..	293
Secondary Turns .	50 to 1.	Secondary Turns .	50 to 1.

Cast Steel Ring No. 3a		*Cast Steel Ring No. 3b .*	
Outside Diam. ...	22.19 Cm.	Outside Diam. ...	22.19 Cm.
Mean	20.61 Cm.	Mean Diam.	22.61 Cm.
Thickness	1.61 Cm.	Thickness	1.62 Cm.
Cr. Sec. Area.....	2.561 Sq. Cm.	Cr. Sec. Area	2.575 Sq. Cm.
Primary turns ...	451	Primary turns ...	450
Secondary turns..	50 to 1.	Secondary turns..	50 to 1.

Cast Steel Ring No. 4a		*Cast Steel Ring No. 4b.*	
Outside Diam. ...	28.24 Cm.	Outside Diam. ...	22.19 Cm.
Mean	26.65 Cm.	Mean	20.61 Cm.
Thickness	1.601 Cm.	Thickness	1.62 Cm.
Cr. Sec. Area.....	2.619 Sq. Cm.	Cr. Sec. Area.....	2.575 Sq. Cm.
Primary Turns ..	592	Primary Turns ..	450
Secondary Turns .	50 to 1.	Secondary Turns .	50 to 1.

Each ring was wound uniformly with one layer of No. 18 B. & S., double cotton covered wire over a layer of insulating tape lapped one-half. This constituted the primary winding. Over this winding was placed a secondary coil of 50 turns. The insulation between the primary and secondary windings consisted of a layer of mica and the latter winding was composed of No. 36 double silk covered German silver wire; German silver being used in order that changes in the temperature, on account of its low temperature coefficient, might not affect the resistance of the secondary circuit and consequently the results.

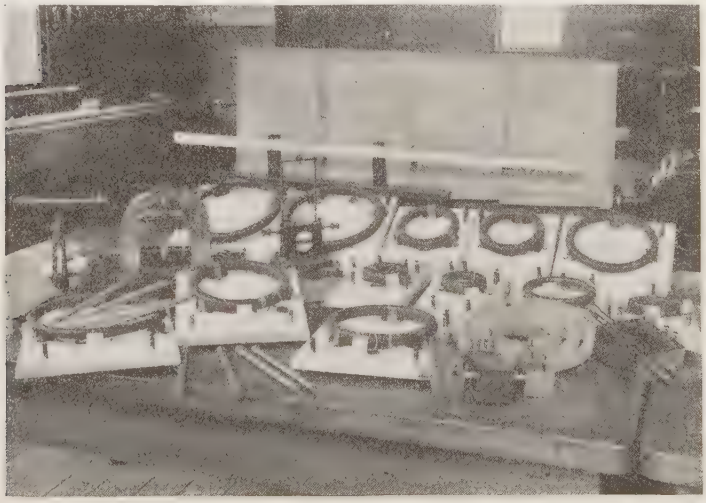

FIG. 1.

As shown in Fig. 1,* the several rings were mounted on suitable bases and the terminals of the primary and secondary windings connected to binding posts. For reasons which will be discussed further on, the secondary winding was connected in the following manner:—

Taps were made at the end of the 1st, 2d, 3d, 5th, 10th, 15th, 20th, 30th, 40th and 50th turns and carried to small binding posts connected with mercury cups as shown in Fig. 2. A second row of mercury cups was placed opposite the first row and between

* Acknowledgment is made to the *Electrical World and Engineer* for the cuts used in this report.—ED.

these was connected a resistance equal to that winding contained between the opposite pair of terminals. The connection was completed by means of a copper clip connecting opposite columns of mercury. It will be seen that this method makes possible the use of a variable number of secondary turns without altering the resistance of the secondary circuit, which enables the operator to keep the deflections of the galvanometer within the range of the instrument, for increasing flux densities, by using a lesser number of secondary turns.

To guard against the criticism that the lack of homogeneity in the steel casting might account for the difference in the results obtained from tests of the samples described above, 4 rings were made of approximately the same dimensions as the steel rings, built up in the following manner:

A quantity of soft steel ribbon ½ inch wide, .01 of an inch in thickness was obtained. This ribbon was cold rolled from nearly pure iron and the surface was bright and smooth. The rings were built up by winding the strip metal until a ring was obtained of approximately the same cross-section as the cast steel samples, as shown by the following table of dimensions. These rings were given a winding similar to that placed on the cast specimens:—

Laminated Ring No. 1c, without insulation.	
Outer Diam.	9.894 Cm.
Mean Diam.	8.601 Cm.
Thickness	1.269 Cm.
Cr. Sec. Area.....	1.612 Sq. Cm.
Primary Turns ..	162
Secondary Turns .	50 to 1.

Laminated Ring No. 2c, without insulation	
Outer Diam.	15.872 Cm.
Mean Diam.	14.590 Cm.
Thickness	1.269 Cm.
Cr. Sec. Area.....	1.585 Sq. Cm.
Primary Turns ..	307
Secondary Turns .	50 to 1.

Laminated Ring No. 3c, without insulation.	
Outer Diam.	21.872 Cm.
Mean Diam.	20.610 Cm.
Thickness	1.269 Cm.
Cr. Sec. Area.....	1.612 Sq. Cm.
Primary Turns ..	447
Secondary Turns .	50 to 1.

Laminated Ring No. 4c, without insulation.	
Outer Diam.	27.922 Cm.
Mean Diam.	26.650 Cm.
Thickness	1.269 Cm.
Cr. Sec. Area.....	1.612 Sq. Cm.
Primary Turns ..	588
Secondary Turns .	50 to 1.

A third casting of cast-steel was obtained and rings were cut from this with dimensions as given in the following table:—

Ring	No. 10.	No. 20.	No. 30.	No. 40.
Outside Diam.	9.892	15.164	20.183	25.37
Mean Diam.	8.6	13.88	18.84	24.1
Cr. Section,	1.8712	1.8371	1.8307	1.8852
No. of Primary Turns,	181	303	448	588
No. of Secondary Turns,	600	600	600	600

A primary winding of No. 16 B. & S., double cotton covered wire placed on the specimens and a secondary winding of 600 turns, with taps at the 5th, 10th, 15th, 25th, 40th, 75th, 125th, 200th, 300th, 400th, and 600th turns, was wound.

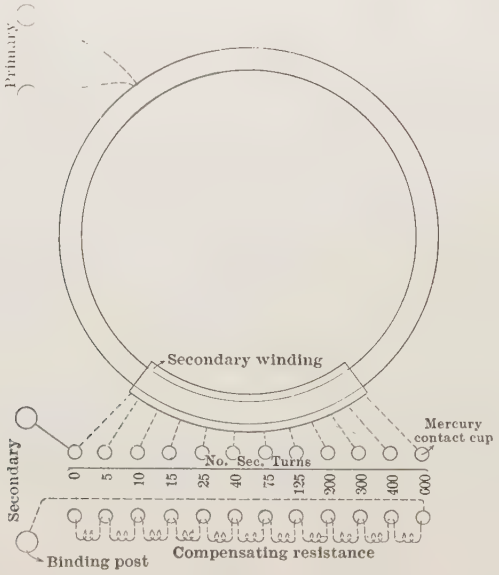

FIG. 2.

A large number of secondary turns was employed in order to necessitate the use of a high resistance in series with the galvanometer when the whole number of secondary turns was in use, for reasons which will be brought out later.

From the cast-steel plate were cut two bars 10 inches long which were turned to a diameter of .575 inch. These bars were tested in a direct reading magnetic testing apparatus shown to the left in Fig. 1. This gives a comparison between the Rowland ring method and the results given by the apparatus.

The Galvanometer.—The galvanometer used was of the D'Arsonval swinging coil type, the suspensions of which were lengthened to $3\frac{1}{2}$ feet each, to reduce the effect of torsion. The resistance of the galvanometer coil was approximately 900 ohms. The usual accessories in the way of telescope, commutator, etc., were provided.

Standardizing Apparatus.—For standardizing the instrument a solenoid was constructed consisting of a core of hard red fiber 187 centimeters in length and 3.82 centimeters outside diameter. This coil carried a primary winding of 1520 turns of No. 18 B. & S., double cotton covered wire. The secondary winding of the coil

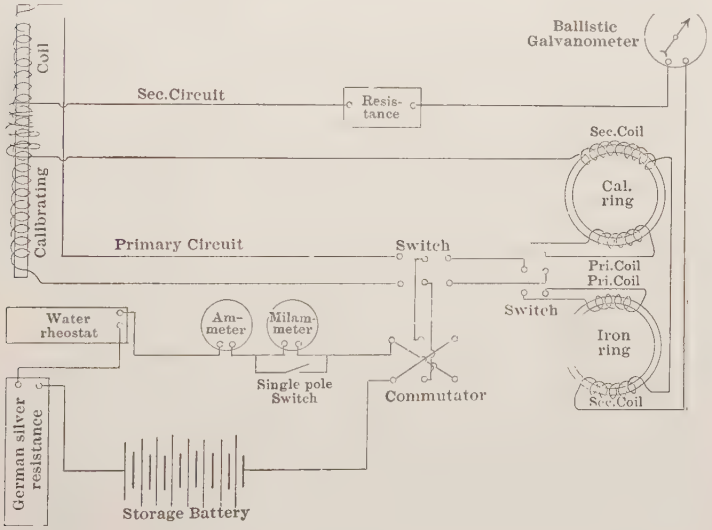

Fig. 3.

consisted of 2000 turns of No. 36 B. & S., double silk covered wire wound in two layers over a length of 6 inches at the middle of the coil.

A set of standardizing coils was also made in the following manner:—

After the cast steel rings were machined to size, a paraffine mold was made from each ring, and from each mold a plaster-of-Paris ring was cast, which received a primary winding similar to that of the specimen and a secondary coil of 600 turns. The

apparatus was connected as shown in Fig, 3. Current was taken from a storage battery to insure steadiness and its value indicated by a standard Weston ammeter.

The Tests.—The galvanometer was adjusted to a period of 24 seconds; each ring was thoroughly demagnetized before taking observations and the instrument standardized before and after each test, using the solenoid and plaster-of-Paris ring of the size of the specimen under test, Each value determined was the result of 8 or more readings.

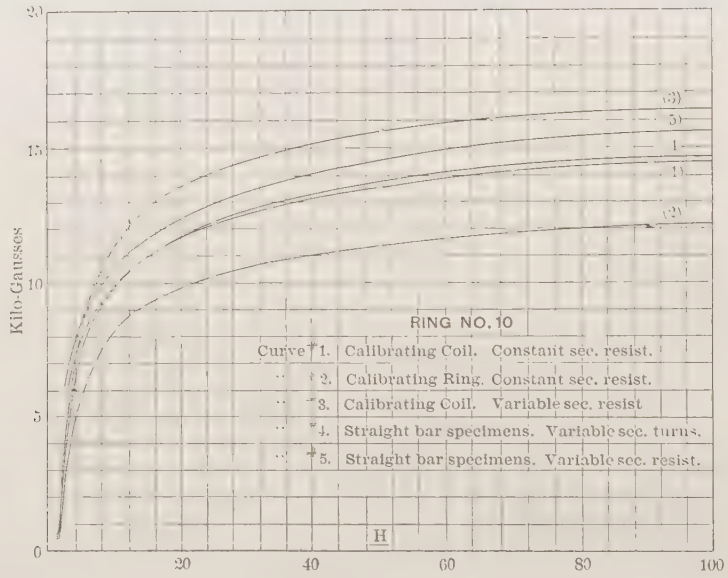

FIG. 4.

The completed test was carried through on each specimen maintaining the resistance of the secondary circuit constant the readings of the instrument being kept within range by the use of a variable number of secondary turns. When the test by this method had been completed, the specimen was demagnetized and tested a second time using the total number of secondary turns and varying the secondary resistance to keep the readings of the instrument within readable range.

The value of H, the magnetizing force in Gilberts per centimeter, was calculated from the equation

$$H = \frac{4\pi\ N\ i}{10\ L}$$

where H is the magnetizing force in Gilberts per centimeter,
N is the number of primary turns,
I is the primary current in amperes,
L is the mean length of the magnetic circuit in centimeters, equal to the mean circumference in the case of a ring specimen.

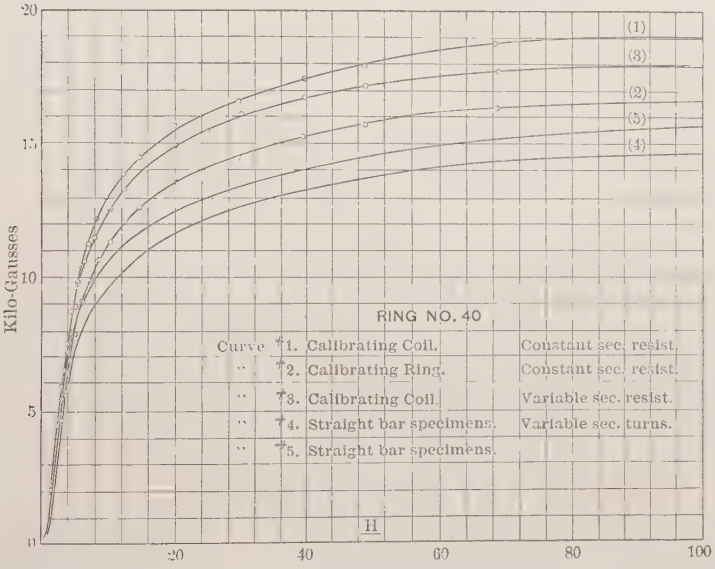

Fig. 5.

The value of B, the maximum density in gausses was calculated as follows:—

(a) With constant secondary turns and variable secondary resistances.

$$B = \frac{4\pi\ n_1 n'\ a\ i_1 R_2 D}{10\ A\ T_2\ r_2\ d}$$

$$= \frac{4\pi\ n\ n'\ a}{10\ T_2 r_2} \left(\frac{i}{A\ d}\right) R_2\ D$$

Where n = number of secondary turns in the standardizing coil.
n' = number of primary turns per centimeter on the standardizing coil.
a = cross sectional area of standardizing coil.
T_2 = the number of secondary turns on the specimen.
r_2 = the resistance of the secondary circuit during standardization.
i_1 = current in the primary of the standardizing coil.
A = the area of the specimen in sq. cm.
R_2 = the secondary resistance during test.
d = reading of the galvanometer during standardization.
D = reading of the galvanometer during test.

(b) With variable secondary turns and constant secondary resistance.

$$B = 4\pi n n' a \left(\frac{i}{d} \frac{}{a}\right) \frac{D}{T_2}$$

Since the secondary resistance is constant during the test and the secondary winding of the standardizing coil may be left in the circuit at all times, the factors R_2 and r_2 become equal and disappear from the equation.

(c) Constant secondary resistance, variable secondary turns and plaster ring calibrating coil,

$$B = 4\pi n n' \left(\frac{i}{d} - \frac{D}{T_2}\right)$$

In this case the cross sectional areas of the specimen and the calibrating coil, as well as the resistances R_2 and r_2, are equal and disappear from the equation.

Results.—The results were calculated with great care and the curves plotted as shown in Figs. 4, 5, 6, 7, and 8.

In each case these results indicate a very wide range in the results obtained by the different methods of standardizing as well as between the tests made using constant and variable secondary resistances. It is clear that the standardizing solenoid using a variable secondary resistance gives in each case the highest values.

This is due to the reduction in the damping of the galvanometer with the increased secondary resistance required at the higher densities. The coil of the instrument swinging in the magnetic field acts as a small electric generator tending to drive the current through the secondary circuit. This current reacts upon the magnetic field and tends to stop the motion of the coil. The greater the secondary resistance, the smaller will be the current set up by the motion of the coil, and consequently a reduction in the damping effect. This makes the galvanometer more

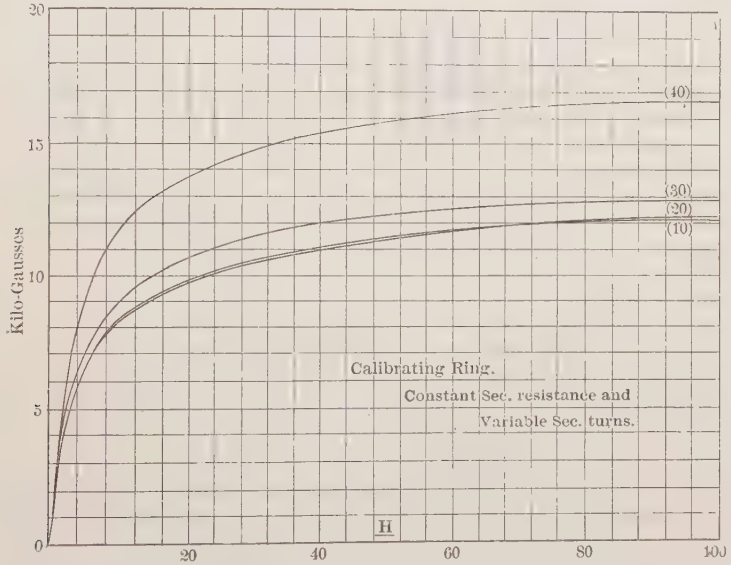

Fig. 6.

sensitive as the higher resistances are introduced and gives results which are too high.

Singularly, the calibrating ring consistently gives results which are lower than the average and which differs from those given by the standardizing solenoid by as much as 36 per cent. of the former.

It is interesting to note that in every case the results by the calibrating solenoid with variable secondary turns and constant resistance curves, No. 1, Figs. 4, 5, 6 and 7, gives results which check very closely with the tests of the straight bars under similar conditions as shown by curves No. 4 of the same figures.

When accurate tests of carefully prepared specimens made by the same operator give results which vary as widely as those just referred to, the need of a standard method of testing is apparent.

There is no doubt but that the use of a constant secondary resistance, which may be effected by using a variable number of secondary turns, or by a key which will throw the galvanometer on open circuit as soon as the charge is passed, will result in results of much greater accuracy.

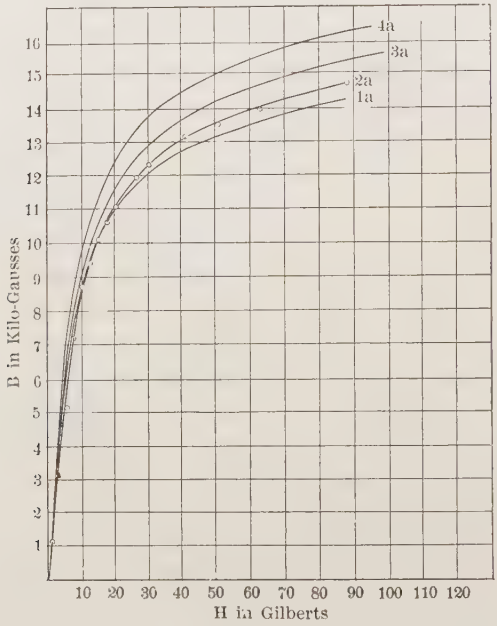

FIG. 7.

Fig. 8 gives the results obtained from similar tests of the four rings, Nos. 10, 20, 30 and 40, and shows a wide variation, due perhaps to the different size of rings and a variation in the quality of the metal in the casting from which the rings were cut. No. 40, the larger ring, giving results which depart widely from those obtained from the other three.

The results from tests of the two sets of four rings cut from a steel casting indicate that variable results may be obtained by using rings of different sizes, the smaller rings giving the lower

values. The results from the smallest ring differ from that of the largest by 14 per cent. of the former.

Possible Errors in the Method of Testing.—In the process of these investigations several probable sources of error were noted, some of which have already been mentioned.

(1) Changes in the sensitiveness of the instrument due to change in damping effect.

(2) It was found that the insulation between the primary and secondary windings should be very high, even if electro-motive

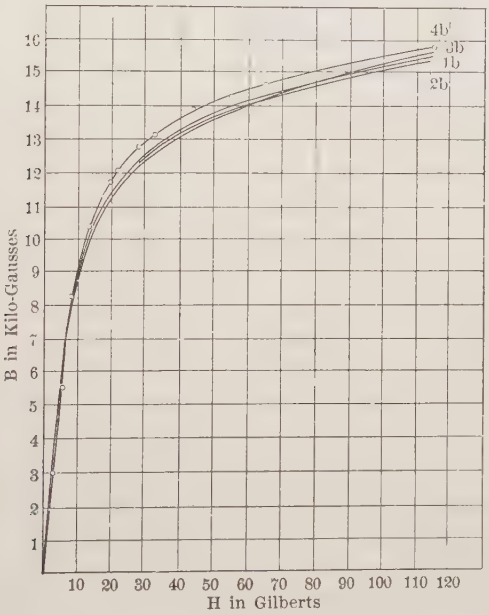

Fig. 8.

forces of low value are employed. Shellac, varnish, tape or any substance which will be affected by heat and thereby cause a reduction in the resistance should not be used.

If the secondary winding is placed over the primary in a single layer, there is a difference of potential impressed upon the secondary circuit and the resistance between the primary and secondary, equal to the drop in that portion of the primary winding which is covered by the secondary, and unless the insulation

between the primary and secondary windings be of high value and permanent in character, a current will be set up through the galvanometer due to leakage. This current, of course, will be very small and cannot be detected by ordinary instruments. If a sensitive galvanometer, however, be used it is detected by a permanent change in the zero reading of the instrument so long as the current is flowing in the primary of the coil. This change of zero increases as the primary current is increased and shifts from right to left, or vice versa, when the primary current is reversed.

This error may enter in the standardization of the instrument due to leakage in the standardizing coil or in the actual test of the specimen when the insulation between its windings is imperfect.

In the winding of a solenoid, the error may be eliminated by winding the secondary in two layers, bringing both ends at the same point. The leakage into the two layers of winding will then be ineffective as no difference of potential will exist between the ends of the secondary coil.

REPORT OF COMMITTEE H ON STANDARD TESTS FOR ROAD MATERIALS.

The Committee on Standard Tests for Road Materials respectfully reports the following:

This Committee was appointed subsequent to the last annual meeting of the Society. It held its first meeting on February 8 last, for the purpose of organization. Of those invited to serve on this Committee, eighteen have accepted. The following Sub-Committees were appointed:

(1) Macadam Tests.
(2) Asphalt Tests.
(3) Wood Paving Blocks.
(4) Road Building Problems.

The only sub-committee which has reported is that on Macadam Tests. This sub-committee has a number of tests under investigation, among which specifications for the abrasion test for macadam rock were presented to the committee at its meeting, on June 17, and accepted, and are now offered to the Society for adoption. It is hoped during the ensuing year that sufficient data will be accumulated from investigations, now being conducted, to frame specifications for several other important tests.

The specifications for the abrasion test are as follows:

This well-known test is similar in almost all respects to the Deval abrasion test of the French School of Roads and Bridges. It has been used since 1878, and is entirely satisfactory for the purpose for which it was designed.

The machine shall consist of one or more hollow iron cylinders; closed at one end and furnished with a tightly fitting iron cover for the other; the cylinders to be 20 cm. in diameter and 34 cm. in depth, inside. These cylinders are to be mounted on a shaft at an angle of 30° with the axis of rotation of the shaft.

At least 30 pounds of coarsely broken stone should be available for a test. The rock to be tested should be broken in pieces as nearly uniform in size as possible, and as nearly 50 pieces as

possible should constitute a test sample. The total weight of rock in a test should be within 10 grams of 5 kilograms. All test pieces should be washed and thoroughly dried before weighing. 10,000 revolutions, at the rate of between 30 and 33 to the minute, must constitute a test. Only the percentage of material worn off which will pass through a 0.16 cm. (1-16 inch) mesh sieve should be considered in determining the amount of wear. This may be expressed either in the per cent of the 5 kilograms used in the test, or the French coefficient, which is in more general use, may be given; that is, coefficient of wear $= 20 \times \frac{20}{W} = \frac{400}{W}$. "W" being the weight in grams of the detritus under 0.16 cm. (1-16 inch) in size per kilogram of rock used.

Respectfully submitted,

LOGAN WALLER PAGE,
Chairman.

A. N. JOHNSON,
Secretary.

SPECIFICATIONS FOR STEEL RAILS OF THE AMERICAN RAILWAY ENGINEERING AND MAINTENANCE OF WAY ASSOCIATION, AS AMENDED AND ADOPTED IN MARCH, 1904.

With Introduction by William R. Webster, *Chairman.*

As a matter of record I desire to present to the Society a copy of the Specifications for Steel Rails, as amended and adopted by the American Railway Engineering and Maintenance of Way Association last March. These specifications differ from those adopted by this Society mainly in the following points:

First. A drop test is required from each heat of steel instead of one from every fifth heat.

Second. The height of drop for rails 65 pounds and over has been increased to—18 feet for 65 to 75-pound rails, 20 feet for 75 to 85-pound rails, and 22 feet for 85 to 100-pound rails, instead of 17 feet, 18 feet and 19 feet, respectively.

Third. The standard length has been increased to 33 feet, with shorter lengths by even feet down to 27 feet, instead of 30 feet and 24 feet, respectively.

Fourth. A clause has been added regulating the finishing temperature.

STANDARD SPECIFICATIONS FOR BESSEMER STEEL RAILS.

Process of Manufacture.

1. (*a*) The entire process of manufacture and testing shall be in accordance with the best current practice, and special care shall be taken to conform to the following instructions:

(*b*) Ingots shall be kept in a vertical position in the pit heating furnaces until ready to be rolled, or until the metal in the interior has time to solidify.

(*c*) No bled ingots shall be used.

(*d*) Sufficient material shall be discarded from the top of ingot to insure sound rails.

Chemical Composition.

2. Rails of the various weights per yard specified below shall conform to the following limits in chemical composition:

	50 to 59 Pounds. Per cent.	60 to 69 Pounds. Per cent.	70 to 79 Pounds. Per cent.	80 to 89 Pounds. Per cent.	90 to 100 Pounds. Per cent.
Carbon	0.35–0.45	0.35–0.48	0.40–0.50	0.43–0 53	0.45–0 55
Phosphorus, shall not exceed	0.10	0.10	0.10	0.10	0.10
Silicon, shall not exceed	0.20	0.20	0.20	0.20	0.20
Manganese	0.70–1.00	0.70–1.00	0.75–1.05	0.80–1.10	0.80–1.10

Drop Test (one from each heat).

3. One drop test shall be made on a piece of rail not less than four feet and not more than six feet long, selected from each blow of steel. The test piece shall, preferably, be taken from the top of the ingot. The rail shall be placed head upwards on the supports, and the various sections shall be subjected to the following impact tests under a free falling weight:

	Weight of Rail. Pounds per yard.			Height of Drop. Feet.
	45 to and including		55	15
More than	55	"	65	16
More than	65	"	75	18
More than	75	"	85	20
More than	85	"	100	22

If any rail break when subject to the drop test, two additional tests will be made of other rails from the same blow of steel, and if either of these latter tests fail, all the rails of the blow which they represent will be rejected, but if both of these additional test pieces meet the requirements, all the rails of the blow which they represent will be accepted.

Shrinkage allowance (for rails 33 ft. long).

4. The number of passes and speed of train shall be so regulated that on leaving the rolls at the final pass the temperature of the rail will not exceed that which requires a shrinkage allowance at the hot saws of 6 inches for 85-pound and 6½ inches for 100-pound rails, and no artificial means of cooling the rails shall be used between the finishing pass and the hot saws. The above shrinkage allowance may be varied, if necessary, so as to give a finishing temperature of not exceeding 1,600° F. at finishing rolls for mills rolling from reheated blooms and not exceeding 1,750° F. at finishing rolls for mills rolling direct from the bloom to finished rail

Drop Testing Machine.

5. The drop testing machine shall have a tup of two thousand (2,000) pounds weight, the striking face of which shall have a radius of not more than five (5) inches, and the test rail shall be placed head upwards on solid supports three (3) feet apart. The anvil block shall weigh at least twenty thousand (20,000) pounds, and the supports shall be part of, or firmly secured to, the anvil. The report of the drop test shall state the atmospheric temperature at the time the test was made

6. The manufacturer shall furnish the inspector, daily, with carbon determinations for each blow, and a complete chemical analysis every twenty-four hours, representing the average of the other elements contained in the steel, for each day and night turn. These analyses shall be made on drillings taken from small test ingot. Chemical Analyses.

7. Unless otherwise specified, the section of rail shall be the American Standard, recommended by the American Society of Civil Engineers, and shall conform, as accurately as possible, to the templet furnished by the railroad company, consistent with paragraph No. 8, relative to specified weight. A variation in height of one sixty-fourth (1-64) of an inch less, or one thirty-second (1-32) of an inch greater than the specified height, and one-sixteenth (1-16) inch in width will be permitted. The section of rail shall conform perfectly to the finishing dimension. Section.

8. The weight of the rails will be maintained as nearly as possible, after complying with paragraph No. 7, to that specified in contract. A variation of one-half ($\frac{1}{2}$) of one per cent for an entire order will be allowed. Rails shall be accepted and paid for according to actual weights. Weight.

9. The standard length of rails shall be thirty-three (33) feet. Ten per cent of the entire order will be accepted in shorter lengths, varying by even feet to twenty-seven (27) feet. A variation of one-fourth of an inch in length from that specified will be allowed, and all No. 1 rails less than 33 feet shall be painted green on the end. Length.

10. Circular holes for splice bars shall be drilled in accordance with the specifications of the purchaser. The holes shall accurately conform to the drawing and dimensions furnished in every respect, and must be free from burrs. Drilling.

11. Rails shall be straight when finished, the straightening being done while cold, smooth on head, sawed square at ends, variation to be not over one thirty-second (1-32) of an inch, and prior to shipment shall have the burr occasioned by the saw cutting removed and the ends made clean. No. 1 rails shall be free from injurious defects and flaws of all kinds. Finish.

12. The name of the maker, the weight of rail and the month and year of manufacture shall be rolled in raised letters on the side of the web, and the number of blow shall be plainly stamped on each rail, where it will not subsequently be covered by the splice bars. Branding.

13. The inspector representing the purchaser shall have free entry to the works of the manufacturer at all times when the contract is being filled, and shall have all reasonable facilities afforded him by the manufacturer to satisfy him that the finished material is furnished in accordance with the terms of these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment. Inspection.

14. No. 2 rails will be accepted up to five (5) per cent of the whole order. Rails that possess any injurious defects, or which for any other cause are not suitable for first quality, or No. 1 rails, shall be considered as No. 2 rails; provided, however, that rails which contain any physical defects which impair their strength shall be rejected. The ends of all No. 2 Rails.

No. 2 rails shall be painted white in order to distinguish them. Rails rejected under the drop test will not be accepted as No. 2 rails.

Respectfully submitted,

WM. R. WEBSTER, *Chairman*, Consulting and Inspecting Engineer, Philadelphia, Pa

R. MONTFORT, *Vice-Chairman;* Chief Engineer, Louisville & Nashville Railroad, Louisville, Ky.

F. E. ABBOTT, Inspecting Engineer, Illinois Steel Company, Chicago, Ill.

G. BOUSCAREN, Consulting Engineer, Cincinnati, O.

S. M. FELTON, President, Chicago & Alton Railway, Chicago, Ill.

ROBERT W. HUNT, Consulting Engineer, Chicago, Ill.

J. T. RICHARDS, Chief Engineer, Maintenance of Way, Pennsylvania Railroad, Philadelphia, Pa.

R. TRIMBLE, Chief Engineer, Maintenance of Way, Northwest System, Pennsylvania Lines, Pittsburg, Pa.

G. B. WOODWORTH, Rail Inspector, Chicago, Milwaukee & St. Paul Railway, Chicago, Ill.

Committee.

CHANGES IN THE SPECIFICATIONS FOR MATERIAL AND WORKMANSHIP FOR STEEL STRUCTURES, EDITION OF 1903, AS APPROVED BY THE AMERICAN RAILWAY ENGINEERING AND MAINTENANCE OF WAY ASSOCIATION AT THE ANNUAL MEETING, MARCH 16, 1904.

By J. P. Snow.

At the request of the Secretary I beg to present the following changes in our specification* as presented before you at the Sixth Annual Meeting, held at Delaware Water Gap in 1903, with reasons therefor. The new reading only is here given.

Paragraph 2. The chemical and physical properties shall conform to the following limits:

Elements Considered.	Structural Steel.	Rivet Steel.	Steel Castings.
Phosphorus Max. { Basic	0.04 per cent.	0.04 per cent.	0.05 per cent.
Phosphorus Max. { Acid	0.08 "	0.04 "	0.08 "
Sulphur Max.	0.05 "	0.04 "	0.05 "
Ult. tensile strength .... Pounds per sq. in.	Desired 60,000	Desired 50,000	Not less than 65,000
Elong.: Min. per cent in 8 in. (Fig. 1)	$\frac{1,500,000\dagger}{\text{Ult. tens. str.}}$	$\frac{1,500,000}{\text{Ult. tens. str.}}$	
Elong.: Min. per cent in 2 in. (Fig. 2)	22	.....	18
Character of fracture ...	Silky	Silky	Silky or fine granular.
Cold bend without fracture	180 degrees flat‡	180 degrees flat§	90 degrees.

The yield point, as indicated by the drop of beam, shall be recorded in the test reports.

The important change in this is: the reference to Figs. 1 and 2 in requirements for elongation. It was held that the original could

*Proc. Am. Soc. Test. Mats., Vol. III, pp. 59-68.
† See par. 11.
‡ See par. 12, 13 and 14.
§ See par. 15.

be made to mean that ordinary plates and shapes must be accepted if the specimens showed elongations of 22 per cent in 2 inches when what we desired was about 26 per cent in 8 inches. Reference to the figures is intended to restrict the 22 per cent elongation to pins and rollers. The addition of a heading was thought to make the paragraph more consistent with the reading of the rest of the specification.

Par. 9. Material which is to be used without annealing or further treatment shall be tested in the condition in which it comes from the rolls. When material is to be annealed or otherwise treated before use, the specimens for tensile tests, representing such material, shall be cut from properly annealed or similarly treated short lengths of the full section of the bar.

The results of annealing small test specimens is so unsatisfactory that a short length of the full section of the bar was prescribed as an improvement. It would be desirable to cut the specimen from a bar annealed in the regular bridge shop annealing furnace, but the tests here prescribed should be made at the rolling mill, where such furnaces are not in use, and it seemed an unwarrantable waste of material to require a full-length bar to be annealed from which to cut a small specimen. The phrase "properly annealed" was used to bar out special treatment in a muffle.

Par. 13. Full-sized material, for eye-bars and other steel 1 inch thick and over, tested as rolled, shall bend cold 180 degrees around a pin the diameter of which is equal to twice the thickness of the bar, without fracture on the outside of the bend.

As originally written, this paragraph, read in connection with 9, might allow specimens for bending to be annealed before testing. This was not intended, and the words "as rolled" were inserted to prevent this interpretation.

Par. 16. The clause, "Plates 36 inches in width and under shall have rolled edges," was added to the original. This explains itself.

Par. 33. The last clause was changed to read: "Holes in flanges of rolled beams and channels used in floors of railroad bridges shall be drilled from the solid. Those in webs of same shall be so drilled or sub-punched and reamed."

The original allowed holes in flanges of rolled beams and channels to be sub-punched while the revision requires such holes to be drilled from the solid.

COMPARISON OF THE SPECIFICATIONS FOR AXLES AND FORGINGS, PROPOSED BY COMMITTEES OF THE AMERICAN RAILWAY MASTER MECHANICS' ASSOCIATION, AND THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, WITH THE STANDARD SPECIFICATIONS ADOPTED BY THE AMERICAN SOCIETY FOR TESTING MATERIALS.

By H. V. Wille.

The American Society for Testing Materials has been strongly urging the adoption of Standard American specifications. This result can only be obtained by cooperation with other societies. But after formulating their specifications the American Society have done very little for the furtherance of this purpose. The American Society of Mechanical Engineers and the Master Mechanics' Association are considering the question of forgings, but each Committee has worked independently of the other with the results that we now have more specifications than ever.

In an attempt to harmonize these differences the Chairman of the Master Mechanics' Association made an effort to secure a joint meeting of the Chairmen of the Committee on Forgings of the different societies, and this meeting was attended by Prof. Spangler of the American Society of Mechanical Engineers, Messrs. Vauclain and Pomeroy of the Master Mechanics' Association and by the writer.

It was conceded to be desirable that the American Society of Mechanical Engineers and the American Society for Testing Materials specifications for high steel and the Master Mechanics' specifications for steel axles and locomotive forgings should correspond, inasmuch as the synopses of specifications attached to the American Society for Testing Materials specifications for forgings show that outside of the United States Government the railroads and builders of locomotives are the most extensive users of this grade of steel.

In order to place the makers of basic and acid steel upon

an equal footing, it is also desirable either to raise the limit for phosphorus without any reference to the method of making the steel, or give the basic makers a lower limit and the acid makers a higher one. The standard American practice, however, appears to be to place the limit on phosphorus and sulphur at about 0.05 without regard to the method by which the steel is made.

The following statement shows the difference in the proposed specifications of the different societies:

		A. R. M. M. A.		A. S. T. M.		
	A. S. M. E.—High Steel.	Dr'g Ax's.	Forg's.	Forg's.	Steel Axles.	Compromise suggested for steel Dr'g Ax's and Locom. Forg's and high steel annealed.
Phosphorus	0.04	0.05	0.05	0.04	0.06	0.05
Sulphur	0.04	0.05	0.05	0.04	0.06	0.05
Manganese	.....	0.60	0.60	.....	.....	0.60
Tensile strength	80,000	80,000	80,000	80,000	80,000	80,000
Elongation, per cent	18	20	20	22	18	20
Reduction of area	35	35	35	35	.....	25
Bending 1 by ½ in. test	180° over 1 in. dia.	None	None	180° over 1 in. dia.	.....	180° over 1 in. dia.

This compromise would require the following changes in the various specifications:

American Society of Mechanical Engineers.—Phosphorus and sulphur raised from 0.04 to 0.05; a limitation of 0.60 on the manganese; elongation raised from 18 per cent to 20 per cent in 2-inch section; reduction of area reduced from 35 per cent to 25 per cent.

Master Mechanics' Association.—Reduction of area reduced from 35 per cent to 25 per cent and the addition of a bending test.

American Society for Testing Materials.—Steel Axles. Phosphorus and sulphur reduced from 0.06 to 0.05; manganese. limited to 0.60; elongation raised from 18 per cent to 20 per

cent, reduction of area of 25 per cent and a bending test specified. *Forgings.* Phosphorus and sulphur raised from 0.04 to 0.05; limitation of manganese to 0.60; elongation reduced from 22 per cent to 20 per cent and reduction of area from 35 per cent to 25 per cent.

The manganese is limited because experience indicated that steel is less liable to fail by fatigue when the tensile strength is secured by additions of carbon rather than by manganese.

ALLOY STEELS.

By William Metcalf.

The term Alloy Steels is used chiefly to distinguish steels containing influencing quantities of metals other than iron, from the ordinary steel of commerce known as carbon steel, in which iron and carbon are the influencing elements for use, other elements being considered more as impurities than as useful ingredients. There are three kinds of carbon steel of universal use, Crucible, Bessemer, and Open Hearth. Their discussion does not belong properly to our subject, but it may be observed that they contain small quantities of phosphorus, sulphur, silicon, and manganese, as well as oxygen, nitrogen and hydrogen. Copper and arsenic are present sometimes, but not so generally or in such quantity as to require the careful analyses that are necessary for other ingredients. Certain small percentages of silicon and of manganese are often regarded as useful for special purposes, but not in such quantities as to justify their giving any specific name to the steel.

From time to time we have had put upon the market Silicon Steel, Phosphorus Steel, Chrome Steel, Aluminum Steel, none of which have won any permanent place in commerce.

Of permanent Alloy Steels, we have Nickel Steel, Manganese Steel, Self-hardening or Air-hardening Steel, and the latest, the new variety called High-Speed Steel.

Nickel Steel.

Nickel Steel containing comparatively small percentages of nickel is used chiefly for structural purposes, giving increased strength and toughness: it has been applied mostly to armor plates and gun parts, and lately it is being tested largely in rails to determine whether the increase in durability in difficult places will justify the greater cost over ordinary Bessemer or open-hearth rails.

Manganese Steel.

Hadfield's Manganese Steel is unique; hard, tough, non-magnetic, non-hardening by quenching, non-annealable by any

known method, practically unmachineable, it stands by itself; there is nothing to compare it to, nor to test it by. It is finding large use for a number of special purposes.

SELF-HARDENING, OR AIR-HARDENING STEEL.

This steel derives its name from the fact that when it is heated to any orange color and allowed to cool slowly in the air it becomes exceedingly hard. Some years ago it was known generally as Mushet Steel from the fact that its first development was due to the distinguished metallurgist whose name it bore. The usual composition of this steel is about 2 to 3 per cent Manganese, 4 to 6 per cent Tungsten, and carbon high.

The distinctive, persistent hardness of manganese steel indicates that it is manganese that gives this steel its so-called self-hardening property: this was confirmed many years ago by Langley, who found that steel high in carbon, containing about 4 per cent tungsten and minute quantities of manganese, had no self-hardening property, and that the same steel remelted so as to contain 3 per cent manganese became an excellent self-hardening steel. Langley next showed by his beautiful emery-wheel test, that tungsten is the element that acts as a mordant to hold the carbon in solution at a high temperature, giving this steel its most valuable property, that of remaining hard at a comparatively high temperature, so that a tool made of it could be used for cutting metals at a high speed, the tool continuing to do its work at a temperature caused by the enormous friction of the high speed, that would soften completely and render useless the best carbon-steel tool that could be made. This very useful variety of steel has a large place in the markets, being used for many purposes where its peculiar properties give it great value: it is being rapidly overshadowed, however, by the latest and most surprising steel of all, known as

HIGH-SPEED STEEL.

Air-hardening steel as a rule is not tough, that is to say, if it is made tough it will not be very hard, the edge of a tool will flow: and when it is so hard that it will not flow, then it is so brittle that it will crumble easily, and this limits its usefulness. A few years

ago at the Bethlehem Steel Works, some person, whether he was a blunderer or a genius history does not say, revolutionized the whole machine business.

Either by design or accident he heated a tool made of air-hardening steel until it was nearly melted, and according to the traditions and teachings of the ages the tool was ruined utterly.

Again, either by accident or design this ruined tool was put into service, and to the amazement of everybody it did an unheard-of amount of work. This led to farther experiments and tests, and the Taylor-White process was developed: this process consisted in heating a tool excessively hot and cooling it by successive stages, producing a tool that would cut at enormous speed for metal work and take off chips that developed enough heat to blue them. The process was patented, and therefore it is not necessary to go into a long explanation here, especially as it has been superseded.

The process seems to have been uncertain, that is to say, when a tool was handled just right it produced results that were wonderful, and when the manipulations were not exactly right the results were nil.

The potentialities were so great that nearly all of the leading steelmakers in the world attacked the problem, with the result that the present high-speed steels are in no sense of the word air-hardening. Manganese has been reduced from 3 to 4 per cent to 0.30 per cent to traces, tungsten has been increased to 10 to 20 per cent instead of the usual 4 to 6 per cent, and the carbon is generally less than 1 per cent.

There are about fifty different brands on the market, and of course each one is the best. Perhaps the analysis of two of the leading brands will be interesting:

Tungsten	9.99	18.48
Chr.	2.83	2.90
C.	.60	.79
P.	.010	Not determined.
S.	.010	" "
Si.	Trace.	" "
Mn.	"	.33

Another contains:

Molybdenum	9.65
Chromium	0.00
C.	.66
P.	.016
Si.	.046
Mn.	.22

In one sense, it is chaos; all traditions as to heating are completely reversed, and no one really knows what is the best. One brand is famous for its excellence in one kind of work, another in another kind: no one brand yet seeming to cover all of the ground.

One thing is certain, the machine business is revolutionized, these tools have crowded ordinary lathes, planers, drills, etc., away beyond their capacity, machine builders are remodeling their machines to meet the new conditions, and many of the users are throwing out their old machinery for the new, or else remodeling and strengthening what they have.

There are many records published of the work done by this steel, giving speed per minute, feed, depth of cut, etc., so that it is not necessary to repeat them here. A few illustrations of what can be done may be interesting.

In one case a couple of steel cast bed-plates about 4 ft. wide and 9 ft. long were to be planed. There was nominally a half inch to come off, but the unevenness of the casting made the cut about one inch in places. The surface was hard and gritty from the sand of the mold. Several tools were tried, each one going about half an inch, and then having to be reground. Next one tool cut about two inches without grinding. Finally, a tool was tried that had turned up a large, rusty, cast-iron pulley, without grinding, and it cut clear across the bed-plates and was still in good condition for farther work. It is clear that the cost per pound of that tool cut no figure.

Another party had a great many castings to thread; with dies made of the very best carbon steel, he could at moderate speed thread from 2,000 to 3,000 pieces without grinding. With dies made of high-speed steel, and with his machine running as fast

as he can drive it, he threads from 20,000 to 30,000 pieces without grinding.

Another party turns many pieces of hard brasses, and found it difficult to get a tool that would cut them at all until he tried the right high-speed steel and made a tool that would cut all day without grinding, running his lathes at the highest speed he could get.

The same party bores many cast-iron cylinders, and with tools made of steel that would not cut his brass, he bores eight to ten cylinders without regrinding, and at a speed so great that the cylinders come out too hot to be handled with the naked hand. He tried in his cylinders the steel that cut his brass so well, and it would only bore two to four cylinders without grinding.

Another party drills 2⅜-in. holes, 7 in. deep, in soft steel forgings, drilling a hole in about three minutes. The same steel will not make a good threading die for the same forgings, and for this he uses another brand. Neither of these steels will make a good lathe tool for turning these forgings, and for this work he uses a third brand. All of these brands upon analysis would come within the limits of the analyses given above.

From all of this two things are clear: one is that there has been a marvelous, a revolutionary advance in the machining of metals; the other is that steelmakers have met the demand remarkably.

It is also clear that we do not know yet where we are and there is much to be learned by everybody. The best methods of hardening may not have been found,—it seems that for very high speed work it is necessary to fairly melt the point of a tool and quench it in a strong air-blast and then grind to shape. This would not do for threading dies, milling cutters, etc., for the heat would destroy the tools. Such tools are finished from annealed bars. This high-speed steel can be annealed as nicely as carbon steel, differing in this respect from air-hardening steel. The finished tools are heated in a lead bath to 1,800° to 2,000° F. and are quenched quickly in ordinary tempering oil which must be kept cool by a coil containing circulating cold water. They are then tempered in a bath of heavy oil heated to about 450° F. The tools come out bright and clean and do their work wonderfully well.

The steelmaker has the most to learn; he must find out why

there is such a great difference in the work the steel will do, when there is so little difference in composition. He must find the composition, or mixture, that will come nearest to meeting all of the requirements. He has at command now, Ferro-Manganese, Ferro-Silicon, Ferro-Chromium, Ferro-Tungsten, Ferro-Molybdenum, Ferro-Vanadium and Ferro-Titanium. These alloys are all expensive, except the first two, costing from sixty cents to twelve dollars a pound; therefore the present prices of high-speed steel, which to some people seem to be of the fancy order, are really not excessive.

As far as we know at present the steel-users have not succeeded in making tools that are satisfactory for finishing, and for this purpose they resort to tools of carbon steel after having done the rougher, heavier work with high-speed steel. This difficult may be overcome by proper methods of hardening and tempering, or the steelmakers may find a composition that will make a tool that is as good for finishing as for roughing.

The successful production of the above-named alloys marks a great advance in metallurgy, and now that a demand has sprung up, it is certain that the supply will follow, with certainty and uniformity of composition and reductions of cost.

The making and the utilizing of steel containing practically only carbon and iron, with some modifications made by the use of small quantities of manganese, silicon, tungsten and nickel, have occupied the best minds in the manufacturing and engineering world for many years.

The last half of the nineteenth century saw most wonderful developments produced by the inventions of Bessemer and Siemens, aided by the skill and energy of the brightest engineering minds. At the close of the century it was customary to "point with pride," and to assume that so much had been done and so much was known, that there was no room for more revolutionary changes, and the coming generation had only to tag-along, utilizing these great advances with ease and comfort to themselves, and with blessings upon their predecessors.

Now, in the first five years of the twentieth century we older men find ourselves standing on our heads once more; a revolution has come already, and we can look forward to a splendid opening

for the exercise of the best energy and thought of the succeeding generation.

We enjoyed the struggle and the gains of our time, and we can rejoice with the younger men in the prospect of the great triumphs that are to come for them. Clearly there is still plenty to do, and plenty to learn, and in the doing and learning there will be great pleasure.

DISCUSSION.

The President.—While you are thinking what questions to ask in regard to alloy steels, I will put on the board, the test of a piece of steel as follows: Tensile strength, 91,600 pounds; elongation, in eight inches, 21½ per cent. The President.

That piece of steel was recently made in Altoona by the Thermit process, it being the sinking head in an attempt to weld an engine frame in place, by Thermit. The sinking head was forged out into a bar about three feet long and 1¼ inches in diameter, and gave the above figures on tensile test. The analysis was as follows: Carbon, 1.02 per cent., phosphorus, 0.07 per cent.; sulphur, 0.03 per cent.; manganese, 2.32 per cent.; silicon, 1.23 per cent.

You will note that this is another example of an alloy steel, the strength apparently being obtained by silicon and manganese, rather than with carbon as is customary.

H. H Campbell.—An ingot about fifteen inches square of that steel would have no blow holes, but there would be a central pipe through the whole length. It is perfectly easy to make an absolutely dead steel, but you will have holes from one end of the ingot to the other. In some cases a pipe will form under circumstances that are difficult to explain; as for instance, the hole that often appears in the gate at the bottom of a bottom-cast ingot. That gate is cast under a head of steel of perhaps five feet and yet may have a hole in it through which you could put a straw if the hole were straight. In using too much aluminum or silicon a pipe will be produced. Mr. Campbell.

A. Sauveur.—It seems to me that no such sharp distinction exists between ordinary self-hardening steel and high-speed steel as Mr. Metcalf describes in his interesting paper. These two classes of steel are, if not quite identical, at least very closely related. Ordinary mushet self-hardening steel may be converted into high-speed steel by suitable heat treatment. Mr. Sauveur.

Wm. Metcalf.—I should like to confirm what Mr. Campbell Mr. Metcalf.

Mr. Metcalf. says. It is clear that he has had as much trouble with piping as I have, and anybody that runs into that knows what it means, and I sympathize with him.

With respect to the difference between, or the distinction between air-hardened steel and high-speed steel, there is a distinction. I stated twenty years ago that it is the manganese in air-hardening steel that gives it the peculiar property of hardening when cooled in air slowly, but when the manganese was taken out, and the tungsten left in, it had no air-hardening property at all. You could harden it by quenching, but not by laying it down in the air.

I received a report to-day, and a very interesting one to me, of a steel which contains some pretty high alloys, and very little manganese. The party stated they were afraid to use the steel. They heated it in the ordinary way and it was so soft it bent right over. Then they tried it at a little higher, but it would not cut. Then they heated it up as high-speed steel, and they found it was the best piece of steel they ever had.

There is a very sharp distinction between the two steels as they are known now and we should not confound them. Air-hardening steel contains such a quantity of manganese that you cannot very well soften it. It can only be annealed by keeping it at a good orange heat for twenty-four or forty-eight hours and then burying it in hot ashes in the same furnace, taking some twenty-four to forty-eight hours to cool it down; then it can be machined with great difficulty. But the high speed steel is low in manganese, I have analyzed many samples, and and all of them contain from a trace or no manganese to about three-tenths, and all of them contain from 10 to 20 per cent. tungsten, and they must be cooled suddenly from a very high temperature or they will not harden.

High-speed steel is a perfect revelation. It is different in all its properties as to heat treatment and everything else from anything we have known before. It is beautiful to see, the blue chips coming off from a steel forging perhaps cutting a half inch deep. I have seen them curl off and furnish a beautiful illustration of what we call "temperature" colors, showing the most delicate straw color, shading off into brown, pigeon wing, and finally the blue. The successive temperatures that are caused by the heavy cut of the steel, bringing off chips of such beauty of color that there are

no jewels you could find in any of the stores that equal them. I don't know of any self-hardening steel that would do that. Mr. Metcalf.

J. A. KINKEAD.—High-speed tool steel will work at a red heat, the tool being at a red heat as it is cutting doing, work under conditions under which most steel will not work at all. Mr. Kinkead.

WM. KENT.—Mr. Metcalf mentioned vanadium as one of the alloys. I remember a gentleman in the plow business fifteen years ago who had been buying steel plate to put in his plows, and he discovered their wonderful wearing quality, so he thought of making them himself, and he wrote me about putting up an open hearth furnace. I advised him to have the steel analyzed, and the chemist reported that it contained a considerable quantity of vanadium. I came to the conclusion that the iron from which the steel was made was an accidental importation from Sweden or Austria, and that the vanadium was probably the cause of the remarkable wearing quality. I never had occasion to follow the thing up. The man did not build his furnace. Mr. Kent.

MR. SAUVEUR.—I think, as Mr. Metcalf says, that the high-speed steel is a very wonderful metal, but after all the difference which he has described, between it and self-hardening steel is a difference in degree and not in kind. He has just told us himself that high-speed qualities could be imparted to self-hardening steel by heating it to a sufficiently high temperature. Indeed, this treatment of ordinary mushet steel led to the discovery of what is now known as high-speed steel—I want no more conclusive evidence of the fact that no sharp demarcations can be drawn between the self-hardening and high-speed steel. Mr. Sauveur

MR. METCALF.—I thought I made it perfectly clear that high-speed steel came first from the use of air-hardening steel, but it was found to be so uncertain that it was modified and changed until now instead of having five or more per cent. of manganese, all the steels I have had an opportunity of examining, contain from one-tenth to not more than three-tenths of one per cent. of manganese. In other words, they have taken out of the high-speed steel, the material that gives to air-hardening steel its property and its name Mr. Metcalf.

MR. CAMPBELL.—I think Mr. Sauveur makes an error in saying it is a difference in degree and not in kind. We all know that up to 1 per cent. manganese is not injurious, and in cases of most steels, probably beneficial, but a content of from 1 to 10 per Mr. Campbell.

Mr. Campbell. cent. is most decidedly injurious. Two per cent. may be called the limit for good steel, while over 3 per cent. the metal is perfectly worthless. From 1 per cent. to 10 per cent. the change is in degree, but above 10 per cent. we begin to get manganese steel. From a content of 1 per cent. to a content of 8 per cent. there is nothing to lead any one to expect a change in properties if the percentage is increased, yet it is well known that with a content of from 12 to 14 per cent. we have a most valuable metal which shows a difference in kind and not simply in degree. It seems to me that in this case also there is a difference in kind.

A BRIEF REVIEW OF THE STATUS OF TESTING IN THE UNITED STATES.

By Gaetano Lanza.

When asked by the Secretary of this Society to make an address along these lines, I undertook the task with a good deal of hesitation, realizing that statistics ought to play a very prominent part in such an address, and that the time intervening between his invitation and the meeting was altogether too short to enable me to make them at all complete.

I shall have, therefore, to ask your indulgence in this regard, and, although I have not been able to collect a set of sufficient completeness to publish in connection with this paper, I shall endeavor to base my remarks upon a series that will warrant any conclusions that I may draw.

It seems to me that we may roughly divide the situation regarding testing into two periods, the first being that preceding 1875, and the second the last 25 or 30 years. During the first of these two periods comparatively little interest was taken in testing the strength of materials, at any rate, by the consumer; although the producer had, of course, to take an interest in the chemical and metallurgical questions arising, but comparatively little in the physical.

The work of the British Commission, and of such Englishmen as Eaton Hodgkinson, Peter Barlow, Sir William Fairbairn, and others, which appeared in the neighborhood of 1840, attracted a considerable amount of attention in this country, and indeed, if we look over the files of the Journal of the Franklin Institute of that period, we find that by far the greater part of the articles published upon the physical properties of materials were either written by Englishmen, or had reference to tests made in England. The work of David Kirkaldy, published about 1860, which forced the attention of engineers throughout the world upon the importance of ductility in wrought iron and steel, had, of course, its influence in America, and tended to counteract the idea that tensile strength

was the only important item, this being especially true in the case of boiler plate.

Notwithstanding these facts the number of engineers and others who required physical tests to be made, before accepting material for use in construction, was small, and a great deal of material was bought and sold by brands, based largely upon the general reputation of the firm producing it.

In the days of small buildings and small enterprises, when charcoal iron was easily obtainable, such a practice, although not to be commended, was less harmful than it would be to-day; and indeed, as late as 1883, I met with the case of an engineer of good reputation, who had had an extensive practice, ordering refined iron for a boiler, and not requiring any tests; and this for a building where the safety of hundreds of people was at stake, and who, though shown that the iron furnished, in that case, was exceptionally poor, the fractured section exhibiting a variety of appearances, defended its use, claiming that he supposed it was the same as C No. 1. Fortunately for the occupants and frequenters of the building, he was overruled.

The greater part of the testing performed during the period preceding 1875 was done either by or for the United States Government, and was mostly concerned with cast iron, as is shown in the researches of Major W. Wade and Captain T. J. Rodman. Next to that came such as was done by iron companies.

In the case of timber a very considerable number of tests of small samples had been made by different persons, as Messrs. Trautwine, Haswell, Hatfield and others, as these were easy to make. Comparatively little of this work, however, has stood the test of time.

The erection of the Emery testing machine of 800,000 pounds capacity at the Watertown Arsenal about 1875 marks, approximately, the period when the importance of tests began to be more fully recognized, and this is the beginning of the later period. The spirit prevailing among engineers at the beginning of this period, the erection and operation of this machine, the establishment of the Government Commission, together with the increased interest in testing in European countries, all contributed to force the attention of American consumers and producers upon the importance and value of tests.

The work of this second period—viz: from about 1875 to date—has been marked by constant improvement in methods, in specifications, and in investigations along these lines, as well as by a larger use of testing machinery. I am disposed to classify the testing of this period as follows, viz:

1. Tests intended for the purpose of securing good material and reasonable specifications.

2. Tests of full-sized pieces under the conditions of practice.

3. Investigations made for the purpose of ascertaining the law of variation of the different properties of a substance successively. Such tests are so arranged that all other conditions remain constant, so that we may ascertain the law of variation of those under consideration.

Methods of test required to obtain proper accuracy need, of course, to be carefully considered; and we must bear in mind that the degree of accuracy required in different cases or obtainable in different cases is different.

Taking up these classes separately we have:

1. Tests of this class form the chief object of the work upon which our Society is engaged, and are intended to secure good material and reasonable specifications. Moreover, it is my belief that, in the pursuit of this object, as much credit is due to the manufacturers as to the engineers. The value and importance of this work has been ably set forth by many of those prominent in the work of the Society. Not only will it lead to a greater and greater realization of the importance of making tests and inspections, but it will cause the engineer to insist upon reasonable specifications. Moreover, it will also cause the manufacturers to furnish good material, not only because of a better understanding by the producer, and the consumer, of the work, and of the requirements of the other, but also because the elimination of unreasonable and fantastic requirements will leave the producer free to devote his best energies to the production of good and structurally sound metal, and in addition it will become more and more difficult for the one who neglects these matters to find a market for his product at any price. It is unnecessary, however, to speak farther of this division, as it is so familiar to us all.

2. The second division embraces the testing of full-size pieces under, as nearly as possible, the conditions of practice, and this is

the one that is of the greatest importance to the engineer. Moreover, although the producer may not, at present, realize that he is specially interested in this class of tests, he will soon come to such a realization, inasmuch as it is a fact that a knowledge of the behavior of material when put into actual service must necessarily be the final court to which must, perforce, be referred the value of any specifications that may, at any time, be adopted, and hence, that the results of this class of tests will inevitably determine what modifications, if any, are needed in the specifications for material which is to be used for a given service. Indeed, if at any time it can be shown that certain modifications are needed, in order to secure material which will stand the test of service, such modifications will have to be made, whether convenient or inconvenient, and if, at any time, it can be shown that the quality of material commonly employed for a given service does not stand successfully the test of service, investigations will have to be made to ascertain how to produce material that will stand that test.

Looking, therefore, at the subject of testing, from the point of view of its direct usefulness to the engineer, we are forced to appreciate the fact that this class of tests is of the greatest importance.

Although, in our present state of advancement in this line, it would hardly be possible to formulate standard methods, it is at least very desirable that this Society should not only take an interest in such tests, but also that it should endeavor to become, in time, a sort of clearing house for them, and should use its influence to see to it that they should be made in such a manner that the conclusions drawn from their results may be warranted by the facts.

Probably all that can be done at present is to secure the results of such tests for discussion at our meetings, and for publication in our proceedings, and to bring to bear our combined judgment upon the methods of conducting them, and upon the choice of those for which there is the most urgent need, so that we may be instrumental in bringing about, as speedily as possible, the greatest advance in this direction. Our proceedings do not yet extend over a sufficient number of years to contain many such, and hence we shall have to look elsewhere to ascertain where we stand to-day in this regard. The installation of the Government testing machine of 800,000 pounds capacity at Watertown Arsenal about

1875 gave the impetus to such tests, in America, and although some were made at an earlier date, they were not many.

An attempt to collect the statistics of tests of this class made in the United States during the last thirty years reveals the facts that their number and variety are already very considerable, and that such results as have been obtained have exerted a decided influence upon the formulæ and the constants used in engineering practice, and also that much greater activity in making tests along these lines is very much needed. These facts are of themselves sufficient to justify the foresight of those whose efforts served to bring into being the Watertown machine. It will be well to consider, therefore, what has been already accomplished in some of the principal directions, and what are the lines along which more work of the kind is needed.

Among the earliest tests of full-size pieces are those made upon columns of various kinds. Among these may be mentioned tests upon full-size wrought-iron columns of such dimensions and proportions as are employed in bridges and buildings; this includes ratios of length to least radius of gyration between about 30 and 130. While the greater part of them were made on the Government machine at Watertown Arsenal, quite a number were made by Mr. Bouscaren in 1875 at Pittsburg, at Chicago, and at Edgemoor, and later tests were made at Pittsburg by Mr. C. L. Strobel upon wrought-iron Z-bar columns. The general result of all these furnished a more reasonable basis for computing the strength of wrought-iron columns than those in general use at the time, and which have not yet entirely disappeared. In the light of the results obtained it seems to me that, for columns of the above stated sizes and proportions, the following conclusions are warranted, viz:

1. The breaking strength per square inch of such columns remains nearly constant for different values of l / r up to a value which was fixed by Mr. C. L. Strobel at 90, and by others at a little less.

2. Within the stated limits of l / r the difference of strength between centrally loaded columns with pin ends, and those with fixed ends, was not great. These tests also furnished data from which to obtain empirical formulæ for the strength per square inch of centrally loaded columns for values of l / r greater than 90, but within the limits already stated.

Inasmuch as we are now using columns made of steel instead

of wrought iron, we need an equally extensive set of tests of columns of the same general character, made of such structural steel as is employed at the present time, in order that we may have corresponding figures for use to-day. While I have, thus far, been unable to find any set of tests of full-size steel bridge columns, Mr. Christie having been confined to a 50,000 pounds machine, a little light may be thrown upon the question by a set of tests of eight full-size main rods of locomotives, made in my Laboratory of Applied Mechanics, at the Massachusetts Institute of Technology. These rods were made for us by the Baldwin Locomotive Works, of steel having a tensile strength of about 80,000 pounds per square inch; they were of I section, and had values of l/r varying from 100 to 150. They were subjected to direct compression, the ends being mounted on their usual pins. The results were as follows:

1. The compressive strength per square inch varied from 36,100 to 40,600 pounds, the strongest having a value of $l/r=109$, and the weakest having a value of $l/r=125$, from which it is evident that the variation of 5,000 pounds per square inch in strength was due to differences in the steel, and not to differences in the value of l/r.

2. This corroborates the results obtained by Mr. J. W. Dagron, and presented by him to the American Society of Civil Engineers in 1889, and also the remarks made by Mr. C. L. Strobel on that occasion.

3. Moreover, these values are but little greater than those obtained from tests of full-size wrought-iron columns, *i. e.*, from 30,000 to 35,000 pounds per square inch.

Cast-Iron Columns.—In the case of cast-iron columns of such sizes as are in common use in buildings, sixteen were tested in 1887 and 1888, and two more in 1893, on the Government testing machine at Watertown Arsenal. In 1896 fourteen such columns were tested at Phœnixville for the New York Building Department, four of them in 1896 by Mr. Gus C. Henning, and ten in 1897 by Mr. W. W. Ewing. The total number of those enumerated above was thirty. In only three of these tests did the ratio of length to least radius of gyration exceed 105.

The variation in strength of the different columns tested, which is very considerable, was evidently due partly to differences in quality of the material, but mainly to imperfections in the castings.

Moreover, in connection with the second series, quite a number of tests were made upon the strength of the caps, brackets, etc., of such columns. It is only from tests of this character that reliable data can be secured from which to design cast-iron columns.

Timber Columns.—In the case of timber, by far the greater part of the tests of full-size columns were made at the Watertown Arsenal, though some have been made elsewhere, as those made in the Applied Mechanics Laboratory of the Massachusetts Institute of Technology.

Moreover, while in the tests of full-size columns made some years ago by Professor Johnson for the Bureau of Forestry the machinery used did not weigh correctly, the Bureau has now taken up the work, with a full appreciation of the importance and value of making accurate tests of full-size specimens, and it is a part of their present program to make a large number of them upon a great variety of American woods.

It is well known that the work that has been performed in testing full-size timbers has had a far-reaching influence, and has brought about great changes in the constants, and in the formulæ employed in determining the strength of timber structures.

Concrete.—In view of the fact that there is, at the present time, a great deal of interest taken in the use of concrete, and especially of what is known as reinforced concrete, a number of tests of such material have been, and are being made, some on full-size specimens, and some on small ones. It is important that our conclusions regarding the service that can be expected from it should be based upon tests of the former kind, and that the attempt should be made to reproduce, as far as possible, the conditions of practice.

Masonry.—The number of tests that have been made in America of full-size brick piers, of stone columns, etc., is very small, and extensive series of such tests are very much needed.

In summing up the remarks that have been made regarding columns, it may be said that the most urgent need is for a comprehensive series of tests of full-size steel columns of such sizes and proportions as are used in practice, not only in bridges, buildings, and other structures, but also in the various parts of machinery which are subjected to compression. After this, in importance, comes the testing of full-size compression members of other materials, as cast iron, timber, masonry, etc.

The subject of tests of full-size columns has been treated at some length, both on account of its importance and also because it seems to have attracted more attention than other kinds of tests of full-size pieces; nevertheless, a number of others have been the subject of experimental investigations, and many more are very much needed. Brief mention will, however, be made of them as follows:

Transverse Strength.—In the case of wrought-iron beams a few tests were made at the Watertown Arsenal, and some by Mr. Christie; and Mr. Christie tested also a few steel beams in 1884. An extensive series of such tests is needed upon large beams of such structural steel as is used to-day, in order to secure more positive knowledge regarding their proper working strengths.

Although cast iron is not much used for beams in buildings, there are many places where it, as well as steel, is employed in practice to resist a transverse stress, and others where such transverse stresses are combined with other resistances.

A notable case is that of the arms and of the rims of pulleys, and in this direction very little experimental work has been thus far performed.

In the case of timber beams, which is a subject in which the writer has taken a great deal of interest, much more work is needed, especially so as there are many kinds of timber in regard to which we have no data that can be applied with confidence in the computation of timber structures. While very little information can be gleaned from the former tests of the Bureau of Forestry, it is expected that work under their present program will furnish a large amount of such data. Indeed, a very good beginning has been made in the work reported in the circular which is to be issued in a very short time. As to beams of reinforced concrete and of other kinds of masonry, remarks might be made similar to those regarding full-size columns of such materials.

Riveted Joints.—In the testing of riveted joints containing a considerable number of rivets of wrought iron, the Watertown Arsenal has again led in the number of such tests, but more are needed, both with joints of a complicated nature and also with such steel rivets as are used to-day. Although some work along these lines has been performed by different people, it is far from being adequate to supply the information needed.

As examples of other lines along which some work has been performed upon full-size specimens under the conditions of practice, may be mentioned axles and journals, arches, the joints of trusses both in steel and in timber, eyebars, hooks, chain cable, etc., but in the case of most of them much more investigation is needed.

Besides the above, the subject of impact is almost an unexplored field, and another field of the greatest importance which cannot be too strongly emphasized is that of repeated, and of alternate stresses, such as occur constantly in practice, a portion of this work belonging among tests of full-size pieces, and another portion among those of what I have called the third class of tests.

The above will serve to give a brief outline of the classes of tests which the writer would include under the general head of tests of full-size pieces under, as nearly as possible, the conditions of practice, and to give a very brief and crude summary as to where we stand in America in these lines.

3. Investigations made for the purpose of ascertaining the laws of variation of the different properties of a substance successively.

Such work, in order that it may be of value, must be suitably planned, systematically arranged, and performed with great accuracy; for, if it is not suitably planned and systematically arranged, it is of a desultory nature, and if it is not, also, accurately performed, it leads to incorrect conclusions. Moreover, great care must be taken to avoid drawing conclusions from insufficient data, and from applying the conclusions drawn from a set of tests to cases where all the conditions have not been taken into account, or where conditions are liable to occur in practice which do not occur in the cases experimented upon. As examples of investigations of this kind, upon which more or less work has been performed, are the following, viz:

(*a*) Cement.—In this regard a great deal of work has been done in many places, in many ways, and by a large number of investigators; but in much of it the planning has been lacking in breadth, and in many cases the necessary degree of accuracy has not been observed. It follows, therefore, that the conclusions that can be legitimately drawn from the results obtained are not at all commensurate with the amount of work performed.

(*b*) Effect of heat treatment, not only in the manufacture of the metal, but also in the manufacture of the finished structure, and in that to which it may be subjected in service.

(*c*) Laws of flow of metal and its resisting properties under stresses applied at different speeds, including a study of the laws of impact.

(*d*) Effect of applying stresses beyond the elastic limit, and the causes and influence of interval strains.

(*e*) Repeated and alternate stresses, which is a matter of the greatest importance, and one in which the field open for investigation is very broad. Moreover, in such investigations there are a great many ramifications, as the breaking strength under a given service, the change of elastic properties under such stresses, the effect of temperature upon metal subjected to such repeated and alternate stresses, etc.

(*f*) Influence of chemical composition, of heat, and of mechanical treatment upon the properties of metal. A portion of this work pertains to and is naturally performed at the works, but another portion is of such a nature that it is not likely to be performed there.

(*g*) Metallography.—This work, which has attracted so much attention of late and which is being performed by many people, in many places, and in many ways, belongs in this third class of tests. Moreover, in investigations of this kind, great care is needed to draw conclusions, neither too hastily, nor upon insufficient evidence.

No attempt will be made to enumerate the persons, or the laboratories, where any of this third class of tests have been, or are being performed, but it is important to observe that in all cases the final arbiter of the value of the results obtained must necessarily be the extent to which they can be made to apply to pieces of such sizes and proportions as are employed in practice, and to the conditions that occur in service.

DISCUSSION.

WM. METCALF.—Mr. President, I don't know whether the Society wants to hear any ancient history or not, but the mention of a couple of names by Prof. Lanza carried me back about fifty years. He spoke of Wade and Rodman. Two abler engineers, two more profound and accurate thinkers and observers, I have never met since their day. I was pleased to see that Prof. Lanza gave the manufacturers of ancient times a little credit for taking some interest in the product they turned out. Although there was little testing it was because there were good reasons for it. In 1858 I was put under the care of Major Wade and Captain Rodman. One of the first operations I was engaged in as Major Wade's assistant was a very elaborate and careful series of tests of cold rolled iron made at Jones and Laughlins, and no engineering concern or anybody ever made any more careful tests than they did at that time to ascertain the properties of this one material. Mr. Metcalf.

Major Wade handed me six samples of iron of which he wanted the specific gravity. He said he had been trying it and could not satisfy himself. I tested them three or four times and handed him my results, then he showed me his and we happened to agree to the third place of decimals. Then he showed me that the cold rolled bars were much less dense than the hot rolled bars, although the cold rolled iron was much harder and stronger than the other. This was the first observation of the now well-known fact that the harder you make a piece of iron or steel the lower you make its specific gravity.

I took a great deal of pleasure this morning in listening to the discussion of specifiations for cast iron. I was at the business of making castings for guns at one time, where the government requirements were very specific and rigid. One of the chief requirements was, after the iron had been tested and approved as sufficiently strong for tensile, torsional and transverse resistance, to take a cylinder of an inch bore, one inch thick and about six

Mr. Metcalf. inches long, and find its resistance to water pressure by applying pressure until the water was forced through the walls. The water was squeezed out as if from a sponge, and I never knew a cylinder of that size to burst. After that test the cylinder was filled with wax and pressed again and generally the wax would burst the cylinder; but I have seen a cylinder even with such a stress on it spin out the wax as long as the length of this room without bursting. Finally, we had to take a specimen of iron and load it. I will not say positively what the rule was, but I think about two-thirds the breaking strength, and if the piece failed to stand about five hundred applications of that load the iron was rejected as not being sufficiently elastic.

In making guns, the requirement was a density of 7.26. If it was below 7.24 or above 7.28, the Government reserved the right to reject it absolutely. The minimum tensile strength was 30,000 pounds per square inch from samples taken out of the sinking head of the gun. I may simply illustrate the character of the work we did by saying that in making more than three thousand guns during the war, we didn't have one gun rejected for failure to stand the tests, nor one for failure in the proving, and only a single report of a gun that failed during the war in service, and that report proved to be incorrect.

In the 20-in. gun the casting weighed over 80 tons in the rough. The finished gun weighed 116,000 pounds. The density of the sample of the sinking head was 7.26, the tensile strength 36,000 pounds, plus, per square inch. We had to cast a square piece on the lower end for a hold in the lathe; when that was cut off, from curiosity we drilled a specimen out of it and tested it and it gave us a density, I think, of 7.27, and a tenacity of 42,500 pounds per square inch, showing an increase of 6,000 pounds per square inch due to a head of about 25 feet in the casting.

In thirty years' experience after I left the foundry business I have rarely gotten a casting that will bear comparison to those we used to make, and I think you do need specifications to get your founders up to their work.

Mr. Kent. WM. KENT.—Mr. Lanza's paper reminds me of papers read about thirty years ago before the American Society of Civil Engineers on this same subject. They resulted in the establishment of the U. S. Iron and Steel Test Board in 1875 and the appro-

priation by the Government for building the Watertown testing machine. When the appropriation was discontinued, two years later, the work of the Board stopped. Mr. Kent.

H. H. CAMPBELL.—In testing commercial shapes care should be used to retain as far as possible the original rolled surfaces. Tests have been published showing comparative results on rounds of different diameters, but the comparisons were worthless as the bars were turned down from one common diameter, and the proportion of central core was different in every size. Mr. Campbell.

THE EARLY USE OF 60,000-POUND STEEL IN THE UNITED STATES.

By Samuel Tobias Wagner.

The growing favor with which the proposition to use a single grade of steel for all ordinary structures, and that grade having an average ultimate tensile strength of 60,000 pounds per square inch, is the excuse for the presentation of this paper, which is

Year of Completion and River.	Description.	Ultimate Strength.	Min. Elong. Per Cent.
1874. Mississippi	Arches, St. Louis	100,000 min.	18
1878.	Glasgow Bridge	80,000 to 100,000	10–15
1878. Chicago	Chicago River		
1880. Missouri	Plattsmouth	80,000 min.	12
1881. Monongahela	Smithfield St.	C. 80,000 to 90,000	12
		T. 70,000 to 80,000	18
1882. Missouri	Bismarck	C. 80,000 to 90,000	12
		T. 70,000 to 80,000	18
1882. East River	Brooklyn Bridge	70,000	
883. Niagara	Cantilever	80,000	15
1883. Missouri	Blair	C. 80,000	15
		T. 70,000	18
1883. Williamette			
1883. Ohio	Point Pleasant		
1884. Ohio	Henderson	C. 80,000	15
		T. 70,000	20
1884. Susquehanna	B. & O. R. R	C. 80,000	15
		T. 70,000	18
1885. Arkansas	Van Buren	C. 80,000	15
		T. 70,000	18
1885. Ohio	Ky. and Ind. Cantilever	C. 80,000	15
		T 70,000	18
1886. Harlem	Washington Arch, N Y...	62,000 to 70,000	18
1887. Missouri	Sibley, At. T. & S. F.	C. 75,000 to 85,000	18
		T. 60,000 to 70,000	23
1888. Missouri	Omaha	C. 80,000	15
		T. 70,000	18
1888. Mississippi	Cairo	64,000 to 75,000	20
1889. Ohio	Cincinnati, C. & O	C. 64,000 to 72,000	19–17
		T. 58,500 to 66,500	20–18
1890. Firth of Forth	Cantilever	C. 76,000 to 83,000	17
		T. 67,000 to 74,000	20
1890. Colorado	Red Rock Cantilever	C. 64,000 to 72,000	19–17
		T. 58,500 to 66,500	20–18
1890. Mississippi	Merchants' Br., St. Louis.	67,000 to 75,000	20
1891. Ohio	Cincinnati Cantilever	62,000 to 70,000	22
1892. Mississippi	Memphis Cantilever	Main truss, 69,000 to 78,500.	18
		Rest, 64,000 to 72,500	22
1893. Mississippi	Bellefontaine	62,000 to 70,000	22
1893. Delaware	P. R. R., Philadelphia	Main truss, 62,000 to 70,000.	22
		Rest, 50,000 to 60,000	26
1897. Niagara	Double deck bridge	60,000 to 68,000	20
1898. Niagara	Highway arch	60,000 to 68,000	20

C. represents Compression. T. represents Tension.

not intended to present any new facts, but simply, in a brief manner, attempt to follow the earliest uses of structural steel in this country and especially to review the attempts to produce a 60,000-pound steel over twenty years ago.

Mr. C. C. Schneider presented to this Society a review of the history of the use of steel as applied to bridges in this country, at the Fifth Annual Meeting, held at Atlantic City in 1902, and the writer takes the liberty of using it, at the same time inserting a number of additional structures which were erected between 1878 and 1884. The additions consist of the following bridges: Glasgow, Chicago River, Smithfield St. Pittsburgh, Blair, Williamette, Point Pleasant, and Henderson.

Where data are not supplied it has not been possible to obtain them. The steel for the bridge at Point Pleasant was made by the Cambria Iron Company, whose records were lost in the flood of 1888.

The best obtainable data show that up to about 1886 it was customary to use a steel of much higher tensile strength than that which can now be considered good practice for ordinary structures. This seems to have naturally occurred on account of the desire of engineers to use a high unit stress for a high ultimate irrespective of the danger of nonuniformity and liability of injury of such material under mill and shop treatment. Now that we can look back to it, it seems natural that such should have been the case. It would seem that as early as 1884 very little was known of what we now call a 60,000-pound steel.

The writer has been interested in noting of late that his first practical experience with steel, was with what was then called "soft or mild steel" and that it was probably the beginning of the use of 60,000-pound steel in the United States for structural purposes.

In 1883 while in the employ of the Phœnix Iron Company, of Phœnixville, he was assigned to represent that company in the tests which were made by the United States Navy upon the steel shapes for the U. S. dispatch boat "Dolphin" and the cruisers "Boston," "Atlanta" and "Chicago," constructed under Acts of Congress of August 5, 1882, and March 3, 1883, and built under contract with Mr. John Roach, of the Delaware Iron Shipbuilding and Engine Works, of Chester, Pa.

The history of the reason that mild steel was used for these vessels is interesting, and the specifications and details in obtaining it form the principal excuse for the presentation of these data, which are drawn from the private notes of the writer and from a "Report of the Naval Advisory Board on the Mild Steel used in the Construction of the Hulls, Boilers and Machinery of the 'Dolphin,' 'Atlanta,' 'Boston' and 'Chicago,'" prepared from the records of the Board by Assistant Naval Constructor R. Gatewood, U. S. N.

The Advisory Board above referred to was convened by the Secretary of the Navy on June 29, 1881, to suggest the number and class of vessels needed by the Navy, and in their report to the Department it was divided upon the question as to whether the vessels should be constructed of iron or steel, the majority favoring steel. Abstracts from their report are as follows:

They admitted that the most difficult question to decide was the proper material to be used. The contention was made that the construction of iron vessels had reached a very satisfactory condition and that steel would cost more, and in view of the experimental stage which shipbuilding was passing through at that time in Europe it would not be wise to use it.

The reasons for its use were:

1. Increased saving in weight of hull by reduced dimensions.

2. Increased strength of hull and immunity from danger in grounding.

3. Rapidly increasing success with steel in Europe.

4. The certainty that steel will supplant iron in the near future.

5. The impetus to the general development of steel in the United States by such a step of the Government.

6. The necessity, that when the vessels should be completed, they should be equal to, if not superior to vessels of their class abroad.

Upon this report coming before the Naval Committee of the House, an exhaustive investigation in Committee was made and resulted in a report favoring the use of mild steel with but one dissenting vote.

Among the reasons given in favor of it were:

1. That the quality of the steel required could be produced in this country in sufficient quantity and at a reasonable cost.

2. The Committee was surprised and gratified to learn that the United States at that time was the second country in the world, if not the first, in the manufacture of steel. That specimens of open-hearth steel (which is the best for shipbuilding purposes, as the evidence clearly shows), from several of the largest manufactories in the country, were presented to the Committee. This steel is uniform in character, has a tensile strength of from 55,000 to 63,000 pounds per square inch and a ductility of 30 per cent. It is capable of being folded under heavy hammers without crack or fracture.

The Act of August 5, 1882, contains the following provision as to material: "Such vessels . . . to be constructed of steel of domestic manufacture, having as near as may be a tensile strength of not less than 60,000 pounds to the square inch and a ductility of not less than 25 per cent."

After the contracts were made, instructions were sent to all the Navy Inspectors from which the following extracts are made as representing the best naval practice at that time:

SHIP PLATES.

The test pieces to be submitted to a direct tensile stress until they break, and in a machine of approved character.

The initial stress to be as near the elastic limit as possible; which limit is to be carefully determined by the inspector in a special series of tests. The first load to be kept in continuous action for five minutes. Additional loads to be then added at intervals of time as nearly as possible equal, and separated by half a minute; the loads to produce a strain of 5,000 pounds of original section of the test piece until the stress is about 50,000 pounds per square inch of original section, when the additional loads should be increments not exceeding 1,000 pounds.

CONDITIONS OF ACCEPTANCE.

In order to be accepted the average of the four test pieces must show an average tensile strength of at least 60,000 pounds per square inch of original section, and a final elongation in 8 inches of not less than 23 per cent.

If any single piece shows a tensile strength of less than 58,000 pounds, or a final elongation less than 21 per cent, the piece from which it was cut shall be rejected and the test considered to have failed regardless of its average.

Lots of material which show a greater strength than 60,000 pounds per square inch will be accepted, provided ductility remains at least 23 per cent.

It is interesting to note here that when the specifications were issued by the Navy Department a modification was made in the prescribed requirement for the elongation. It was reduced from 25 to 23 per cent in 8 inches. The reasons given for this change were, that at that time the most severe tests required abroad for similar material were by the French Navy, where an elongation of 20 per cent in 200 millimeters (8 inches equal 203.2 millimeters). It had further been the boast of the American manufacturers that their iron was superior to that in general use in Europe, and that American steel deserved the same reputation. The table hereafter given shows that the average elongation obtained was 25.52 per cent, but at that time the ductility was one of the most troublesome elements to meet and caused the greatest number of rejections.

QUENCHING TEST.

A test piece shall be cut from *each* plate, angle or beam, and after heating to a cherry red, plunged in water at a temperature of 82° F. Thus prepared it must be possible to bend the piece under a press or hammer so that they shall be doubled around a curve of which the diameter is not more than one and one-half times the thickness of the plates tested without presenting any trace of cracking.

These test pieces must not have their sheared edges rounded off, the only treatment permitted being taking off the sharpness of the edges with a fine file.

ANGLES, BEAMS, BULB BARS, TEE BARS, ETC.

In every lot of 20 angles or beams, etc., test pieces to be cut from the webs of two taken at random, one from each. These pieces to be fashioned in the same way and to be subject to the same tests, both tensile and quenching, and to fulfill the same requirements for acceptance as already prescribed for ship plates.

Angle bars to be subject to the following additional tests: A piece cut from one bar in 20 to be opened out flat while cold under the hammer; a piece cut from another bar in the same lot shall be closed until the two sides touch, while cold; a piece from a third bar of the lot shall be bent cold into a ring, so that one of the sides of the angle bar shall be kept flat and the other side forming a cylinder of which the internal diameter shall be equal to one and one-half times the breadth of the side which remains flat. The angle bars submitted to these tests must show neither cracks, clifts nor flaws.

Single "T" bars to be submitted to the following tests: A piece to be cut from the end of a bar taken at random from each lot of 20 and to be bent cold into a half ring, so that, the web remaining in its own plane the cross flange should form a half cylinder, of which the internal diameter shall equal four times the height of the web of the "T" bar.

At the end of another bar of the same lot the web to be split down its

middle for a length equal three times its total depth, and a hole drilled at the end of the slit to prevent its spreading; the piece thus split to be opened out in its own plane, so as to make an angle of 45 degrees with the rest, care to be taken that the part opened shall be kept straight, except that it must be joined to the rest of the bar by a bend of small radius.

Bulb bars are to be submitted to the same tests as those prescribed for "T" bars except that in bending, one or more heats may be used.

All bars submitted to these tests must show neither cracks, clifts nor flaws.

RIVETS.

From every lot of 500 pounds four rivets are to be taken at random and submitted to the following tests, one rivet to be used for each test: First, a rivet to be flattened out cold under the hammer to a thickness of one-half its diameter without showing cracks or flaws; second, a rivet to be flattened out hot under the hammer to a thickness of one-third of its diameter without showing cracks or flaws; third, a rivet to be bent cold into the form of a hook with parallel sides without showing cracks or flaws; fourth, a rivet to be tested by shearing by riveting it up to two pieces of steel which are to be submitted to a tensile strain, the rivet not to shear under a stress of less than 50,000 pounds per square inch.

The Chester Rolling Mills, of Chester, Pa., the Norway Iron and Steel Company, of South Boston, Mass., and Park Bros. & Co., of Pittsburgh, Pa., made the ship and boiler plates; the Phœnix Iron Company, of Phœnixville, the angles, tees and deck beams. Assistant Naval Constructor R. Gatewood and Assistant Engineer B. C. Bryan were assigned to the work at Phœnixville.

At that time the Phœnix Iron Company had no steel mill, and a lot of blooms of Bessemer and open-hearth steel were ordered as an experiment from the Pennsylvania Steel Company, of Steelton, Pa., and the Cambria Iron Company, of Johnstown, Pa. These were rolled into various shapes at Phœnixville, and were tested by the writer in accordance with the Naval requirements. As a result of these tests, combined with what knowledge existed at that time regarding the relative merits of Bessemer and open-hearth steel, a contract was entered into with the Cambria Iron Company to supply the blooms for the shapes required of open-hearth steel, and the writer was sent to Johnstown to accept the blooms from the Cambria Iron Company. At this time the filling of an order of steel to meet these requirements was looked upon as something of an undertaking, as very little material with such low carbon and such high ductility had been manufactured for any important structures.

The steel was made in two 15-ton Pernot revolving furnaces, with 16-foot pans, erected in 1878-79. Ferro-manganese was added before tapping and the bath was rabbled while the furnace revolved. The ingots were top cast and weighed about 5,500 pounds each. One ingot was rolled in the blooming mill as soon as possible and two test billets removed which were hammered down to slabs about three inches thick, reheated, and rolled into 6-inch by 7-16 thick flats, from which the tensile tests were cut. The other ingots were allowed to cool off completely, awaiting the results of the tests, when if satisfactory they were rolled into blooms of ordered sizes. A quenching test was made at the same time.

Considerable difficulty was experienced at first in making the steel. In the first 20 heats made 11 were rejected mainly on account of failure to show the required elongation, and some few failing to pass the quenching test.

In the opinion of the writer, the trouble was caused in part by the fact that when not making this soft steel, the furnaces were making very high carbon steel for springs and agricultural purposes, and on changing from this grade were very apt to miss the next heat or two. This trouble was, however, overcome in a short time, when heat after heat was satisfactorily made.

Large flaws in the blooms were chipped hot in the blooming mill, and it was the practice for some time to examine each bloom when cold and chip the flaws down to solid metal.

The acceptance of the quality of the blooms on the above tests was difficult, because the blooms were rolled at Phœnixville into all kinds of sizes from heavy deck beams to very light angles, and in these shapes were again tested and finally passed upon by the Government inspector. This method was afterwards changed, a Government inspector being sent to Johnstown to accept the steel from the Cambria Iron Company.

At Phœnixville, some trouble was experienced at first in the rolling mills because the heating of steel was new to the heaters, and in a few cases at first some of the blooms were overheated. These bars were generally discovered when the quenching test was made.

The method of making the tests as before noted was very peculiar, and in these later days of expeditious working would have

been looked upon as disastrous. The average time consumed in making 20 tests taken at random was 20 minutes. Later on the time of the application of the first load was reduced from 5 minutes to 1 minute. Taking everything into account on these tensile tests, it was impossible to break more than 20 pieces in a day.

The following table shows the average results of the more important elements of the steel from the shapes:

	Accepted Material.	Rejected For Lack of Elong.	Rejected For Low Ult.	Rejected Quenching Test.
Number of heats	114	10	6	3
Number of tests	483	21	22	12
Average carbon per cent	.160	.162	.133	.166
Average elastic limit	41,440	44,133	36,796	39,153
Average ultimate strength	64,057	65,871	58,284	62,640
Average elongation in 8 in	25.42	21.91	27.11	26.02

At first the division for acceptance under the specification was a lot of 20 pieces, from which were made:

On angles	2 tensile tests.	on all shapes.
	20 quenching tests.	
	1 open test.	
	1 closed test.	
	1 bent ring test.	
On tees	1 ring test.	
	1 split bending test.	
On decks and bulbs	1 split bending test.	

On account of the unavoidable confusion existing by reason of the unit of acceptance being a lot of material which might contain a number of heats, the unit was changed to a *heat*, the same number of tests being prescribed.

After the year 1886 the use of softer grades of structural steel increased slowly, as will be evident from the examination of Mr. Schneider's table, but it seems evident or likely that the effort of the Government to obtain a low-carbon steel with high ductility in 1883 was a very courageous attempt, as there was no precedent for material of that grade in the United States at that time.

Several of the reasons given in the report of the Committee of the House for its use in these vessels seem to have materialized, notably: First, the impetus which such use gave to the steel

industry specially in the introduction and use of low-carbon steels for structural purposes. Second, the fact that iron in the near future would be replaced by steel, as twelve years afterwards, in 1893, the Carnegie Steel Company, in the preface of their Pocket-Book, said: "The feature of this edition is the elimination of all data relative to iron sections. Our product hereafter will be exclusively steel."

Looking back over the whole field, it seems fair to say that the effort to obtain what is now likely to be regarded a standard steel for structural purposes was first attempted by the Government for use in the first steel vessels of our modern navy.

DISCUSSION.

Mr. Kent. WM. KENT.—Perhaps I can add a little to that history. In the year 1882 I was with Shoenberger and Company of Pittsburg. Since 1879 we had been making exactly that quality of steel for sale for boiler plates, and the Otis Steel Works in Cleveland had been making it for some years previously. In 1879 a similar steel, but a little higher in phosphorus, came into use for structural purposes. In 1882 there was brought out by the Government for the first four cruisers of the new navy a set of different specifications with a minimum limit of 60,000 pounds tensile strength and an elongation of 25 per cent. in 8 in., which was more severe than any foreign specifications. That is, at that date there had been no steel made in the world under a specification of not less than 60,000 pounds tensile strength and 25 per cent. elongation in 8 in.

John Roach, owner of the shipbuilding works at Chester, took the contract with that provision in the specifications. He had to make it and he had to find out what was the trouble in making it. He found by a proper manipulation of the slags and the furnaces, and by giving the ingots a sufficient amount of work that the requirements could be met. So the steel was made and made successfully, and the steel put in these four cruisers was the best steel ever made in the world up to that time.

Mr. Bentley. ROBERT BENTLEY.—I was employed at the Chester Rolling Mills during the period referred to by Mr. Kent. The steel was rolled on the old-fashioned mill. The modern method of rolling was not in practice at that time in Chester, all of the steel being rolled on the old two-high trains. And after we learned to make the steel we had another difficulty to overcome, namely, to roll the steel of definite weight and thickness. That was the problem in those days, because we knew nothing about micrometer gages, nothing but the old caliper gages being in use, and we depended very much on the expertness of the rollers to make the plates of the required weights and thickness.

John Roach deserves credit for making the first 60,000-pound

Mr. Bentley. steel for U. S. Government requirements. The furnaces were built and erected under the supervision of Mr. Chas. Ryder. If I remember rightly, Mr. Sloan was the chemist, and I held the position as roller, and much of the material passed through my hands. I know that the steel made at that time was probably as good as any that has been made since. It was all acid steel, and we used charcoal blooms largely in the manufacturing. I doubt whether I have ever handled better steel than I did at that time.

THE CLASSIFICATION OF IRON AND STEEL.

By Albert Sauveur.

Metallic iron is obtained and used in the arts under three different conditions, namely, as wrought iron, steel and cast iron. While cast iron is very highly carburized, wrought iron generally contains very little carbon, and steel a more moderate amount of that element, which amount, moreover, varies according to the grade of the steel, between wide limits. It is to the different proportions of carbon which they contain that these three products of the metallurgy of iron owe their generally very different properties. Cast iron is not malleable and lacks both strength and ductility; it is brittle. Wrought iron, on the contrary, is very malleable, very ductile and fairly strong, while the strength and ductility of steel varies according to its carbon content, the strength increasing and the ductility diminishing with that element. Carburized iron, moreover, containing a sufficient amount of carbon, possesses the invaluable property of becoming intensely hard when suddenly cooled from a high temperature, and, formerly, only those metals which possessed this hardening power were called steel.

While the properties of cast iron, however, are radically different from those of wrought iron, and while the properties of medium high carbon steel are likewise very different both from the properties of cast iron and from those of wrought iron, if we examine the properties of very high carbon steel on the one hand, and of very low carbon steel on the other, we find that the former so much resemble the properties of certain grades of cast iron (white cast iron), and that the latter are so similar to those of wrought iron, that a sharp distinction between these three metals founded upon their properties alone, or upon their composition, is quite impossible. The similarity, not to say identity, in composition and properties, existing between wrought iron and the slightly carburized metal called soft steel, is especially troublesome in any attempt at such a classification.

In order to arrive at any satisfactory nomenclature it is absolutely necessary to take into consideration the method of manufacture by which the metals were obtained. This necessity was recognized by the international committee appointed in 1876 at the instance of the American Institute of Mining Engineers, and which recommended the following classification:

1. That all malleable compounds of iron with its ordinary ingredients which are segregated from pasty masses, or from piles, or from any forms of iron not in a fluid state, and which will not sensibly harden and temper, and which generally resemble what is called "wrought iron," shall be called *weld-iron* (German, *Schweisseisen;* French, *fer soudé*).

2. That such compounds' when they will from any cause harden and temper, and which resemble what is now called "puddled steel," shall be called *weld-steel* (German, *Schweiss-stahl;* French, *acier soudé*).

3. That all compounded iron with its ordinary ingredients, which have been cast from a fluid state into malleable masses, and which will not sensibly harden by being quenched in water, while at a red heat, shall be called *ingot-iron* (German, *Flusseisen;* French, *fer fondu*).

4. That all such compounds, when they will from any cause so harden, shall be called *ingot-steel* (German, *Flussstahl;* French, *acier fondu*).

In this classification very great pre-eminence is given to the hardening power of iron containing a sufficient amount of carbon. Indeed, it is made the criterion by which steel shall be distinguished from iron.

A serious objection to this classification is that the hardening power is not acquired abruptly when a certain amount of carbon is present but very gradually as the proportion of that element increases. To draw a sharp line between carburized irons possessing the hardening power and those lacking that property is an impossible task. These specifications are necessarily silent regarding the nature of the test by which it can be ascertained whether carburized iron is or not sensibly hardened by sudden cooling. The word sensibly is, moreover, altogether too elastic and vague a term to introduce into this nomenclature. Such phrases as "generally resembling what is called wrought iron"

may also be condemned on the same ground. The substitution ot the term weld-iron in place of the universally adopted name of wrought iron is of questionable wisdom, as well as the introduction of the terms weld-steel, ingot-steel and ingot-iron. This classification only retains an academic interest, for it has never been adopted in actual practice, at least not in English-speaking countries nor in France. The name of Flusseisen (ingot-iron), however, has passed into the German metallurgical vocabulary, but even in the German works, where the metal is made, it is called steel.

In English-speaking countries and in France there exists an understanding, tacit at least, to give the name of wrought iron to all irons obtained in a pasty condition, and, therefore, mixed with slag, and to reserve the name of steel for all carburized irons obtained in a molten condition, and, therefore, free from slag. In such a classification much importance is attached to the method of manufacture and, therefore, to the absence or presence of slag in the resulting products. It appears to be, on the whole, the best solution of this difficult problem, for it affords a ready means of properly classifying all iron products, even when in ignorance of the processes by which they were obtained, for the presence or absence of slag, which can be so readily and conclusively ascertained under the microscope, will make it possible to assign to the metal its proper place. It seems, however, desirable to distinguish between these slag-bearing irons obtained in a pasty condition and very free from carbon and those which, although produced by the same methods, contain enough carbon to assume a decidedly steely character. The name of *steely wrought iron*, which is not a new one, appears to be a very appropriate one for products of this description, suggesting at once their nature and making it possible to retain the word steel exclusively for products obtained molten.

In view of these considerations the following classification appears to the writer the best that can be devised:

			Usual Method of Production.
I. Carburized iron obtained in a molten condition and therefore free from slag.	1. Not malleable	*Cast Iron* (gray, mottled, white).	Blast Furnace.
	2. Malleable	*Steel*	Bessemer Process. Open-Hearth Process. Crucible Process
		Malleable Cast Iron (white cast iron made malleable by conversion of combined C into temper C	Malleable Cast Iron Process.
II. Iron obtained in a pasty condition and therefore containing slag.	1. Containing less than 0.25 per cent C, *Wrought Iron*		Direct Processes (Catalan, Bloomeries, etc.), Fineries, Puddling.
	2. Containing over 0.25 per cent C, *Steely Wrought Iron*		
	3. Iron carburized by cementation *Cemented or Blister Steel*		Cementation Process.

In the appendix accompanying this paper other classifications are reproduced as well as the opinions and comments of several authoritative writers.

As Secretary of Commission 24 of the International Association for Testing Materials, appointed to study the uniform nomenclature of iron and steel, the writer hopes that this short paper will lead other metallurgists and engineers to contribute to the discussion of this question.

APPENDIX.

GENERAL CLASSIFICATION PROPOSED BY PROFESSOR HENRY M. HOWE.

The following classification proposed by Professor Henry M. Howe is described at length in his "Iron, Steel and Other Alloys":

General Classification of Iron and Steel.

		With Very Little Carbon.	With a Moderate Amount of Carbon.	With Much Carbon.
Slag-bearing or Weld-metal Series.		WROUGHT IRON.		
		PUDDLED IRON. BLOOMARY OR CHARCOAL IRON.	*Weld Steel.* *Puddled Steel.* *Blister Steel.*	
Slagless or Ingot-metal Series.	Normal or Carbon Group.	*Soft Steel or Ingot Iron.*	*Half-hard and Hard Normal or Carbon Steel.*	MALLEABLE CAST IRON. NORMAL CAST IRON.
		Bessemer Open-Hearth Crucible (Mitis).	*Bessemer Open-Hearth Crucible.*	WHITE, MOTTLED, GRAY, SILVERY, WASHED-METAL.
	Alloy Group.		*Alloy Steels.*	ALLOY CAST IRONS.
			Nickel Steel. *Tungsten Steel.* *Manganese Steel.* *Chrome Steel.* *Silicon Steel.*	FERRO-TUNGSTEN. FERRO-MANGANESE. FERRO-CHROME. FERRO-SILICON. SILICO-SPIEGEL.
Per Cent Carbon.		0 to 0.3	0.3 to 2.0	2.0 to 4.5 to 6.0

NOTE.—In order to make this table clearer, a special type is used for each of the three great classes, wrought iron, steel and cast iron. The wrought iron is given in Roman capitals, all the different varieties of steel in Italics, and all the different varieties of cast iron in Roman small capitals.

THE AMERICAN NOMENCLATURE OF IRON PRODUCTS—BY H. H. CAMPBELL.

In his recent book on the "Manufacture and Properties of Iron and Steel," H. H. Campbell comments as follows on the "American Nomenclature of Iron and Steel":

The classification by hardening is a dead issue in our country. It had quietly passed away unnoticed and unknown before the Committee of the Mining Engineers had met, and the best efforts of that brilliant galaxy of talent could only pronounce a kindly eulogy.

Strictly speaking, some mention must be made of hardening in a complete and perfect definition, for it is possible to make steel in a puddling furnace by taking out the viscous mass before it has been completely decarburized; but this crude and unusual method is now a relic of the past, and may be entirely neglected in practical discussion. No attempt will be made here to give an ironclad formula, but the following statements portray the current usage in our country:

1. By the term wrought iron is meant the product of the puddle furnace or the sinking fire.

2. By the term steel is meant the product of the cementation process, or the malleable compounds of iron made in the crucible, the converter, or the open-hearth furnace.

This nomenclature is not founded on the resolutions of committees or of societies. It is the natural outgrowth of business and of fact, and has been made mandatory by the highest of all statutes—the law of common sense. It is the universal system among engineers, not only in America, but in England and in France. In other lands the authority of famous names backed by conservatism and governmental prerogative, has fixed for the present, in metallurgical literature, a list of terms which I have tried to show is not only deficient, but fundamentally false.

On the Definitions of Pig Iron, Wrought Iron and Steel—A. Pourcel, International Association for the Testing of Materials.

Perhaps the time has arrived to realize the wish expressed at the Düsseldorf meeting in 1880, by the lamented Dr. W. Siemens ("Journal of the Iron and Steel Institute," 1880, Vol. II, page 439) to establish a general understanding on what ought to be called *wrought iron*, and what *steel*.

It is in the hope of attaining this object that the present note, which has been drawn up by the author as one of a sub-committee of the French Commission for the Study of Methods of Testing, is offered for discussion by the International Congress on Methods of Testing.

Inquiry into Certain Definitions.—Iron is used associated with carbon, and according to the degree of carboration serves the most multifarious uses.

It is impossible to separate very sharply the different classes of its compounds; it is usual, however, to divide their long series into three parts: *pig iron*, *steel* and *wrought iron*.

Pig Iron.—This is the raw product in the cast state of the reduction of iron ores. The proportion of the bodies other than iron, and amongst which carbon generally predominates, reaches a variable amount. The melting point varies between 1,050° and 1,300° centigrade.

Pig iron cannot be forged. Sometimes, however, it is enabled to acquire, "to a certain extent," the property of undergoing work by the hammer; then we have malleable cast iron, in which an important part of the carbon is in the state of invisible graphite.

Steel and Wrought Iron.—These products are distinguished from pig iron by containing as a rule less of carbon* and foreign bodies other than iron; by being malleable, and having a melting

* Many white pig irons contain only 1.4 per cent to 1.8 per cent of carbon; natural steels contain 1.6 per cent to 2 per cent. The natural steels are produced in Styria, Westphalia, and other parts of the South of Europe by the partial decarburization of pig iron on the finery.

point between 1,200° and 1,500° centigrade. But there are different opinions as to what should be called properly *steel* on the one hand, and *wrought iron* on the other.

First Opinion.—From the chemical standpoint, there are included under the name of *steel*, in the strict sense of the word, the malleable compounds of iron having a certain content of carbon, and which are characterized by the extreme hardness which they acquire by quenching. Under the name *wrought iron* are included the malleable compounds of iron having a smaller content of carbon, often quite as hard "as non-quenched steels," but not capable of being hardened to the same extent by quenching.

Second Opinion.—It has been proposed to call:

Wrought iron every iron product which is malleable and formed by welding;

Steel every iron product which is malleable and has passed through the fused condition.

In this connection the great influence of fusion has been justly remarked upon. In *welded iron* products formed of elements more or less carburized, cinder is always found between the grains of the metal; the quality of the product also depends in a great measure on the workman.

The iron products which have passed through the fused state are obtained at a high temperature; there is complete liquation between cinder and metal. The elementary (or constituent) bodies formed by cooling are welded together without the interposition of cinder. The quality of the product in this case does not depend on the skill of the workman, but on the quality of the raw materials. The resulting metal possesses those peculiar properties which explain why American, English, Belgian, French and other metallurgists have adopted the name of *steel* for every iron product which is cast and malleable.

Cast steel is easily recognized by applying the appropriate methods. The structure of *welded iron* is such that the presence of the cinder can be recognized by examining the fracture with naked eye, or with microscope; either directly or after a chemical or mechanical operation; whilst in the cast steel there is no cinder, or if there is, it is of local occurrence.

Mr. Grüner would by no means accept this distinction and raised the following objection to it: "It would be strange if a

simple physical operation, fusion, should have on the actual properties and the name of metal a greater influence than its chemical nature."

It may perhaps be observed from what has already been said, that the influence of fusion on the chemical nature of the metal is very considerable all the same.

Third Opinion.—The distinction between wrought iron and steel should be based solely on the property of hardening by quenching or not.

Steels would be those malleable iron products which from any cause whatever harden by quenching.

Wrought iron would comprise those malleable iron products which do not harden sensibly by quenching.

According to the French customs law, the duty on *steel* is only applicable to those steels which harden by quenching.

But the customs tariff contains the following clause:

"The other steels are subject to the same duty as wrought iron, whatever quantity of cinder they may contain."

This phrase clearly points to the admission that there are steels which do not harden by quenching. Nevertheless, the present opinion is that arrived at by the international committee assembled at Philadelphia in 1876, which numbered among its members MM. Lowthian Bell (Sir Lowthian Bell, Bart.) and L. Grüner, the latter as a corresponding member. Wrought iron then being separated from steel by property of *hardening by quenching*, the following distinctions were made:

1. Weld iron, Schweisseisen, fer soudé; Ingot-iron, Flusseisen, fer fondu;

2. Weld steel, Schweissstahl, acier soudé; Ingot-steel, Flusstahl, acier fondu.

These very divisions are indicated in an official order under date January, 1889, addressed to the German Railway Companies, with the view to establishing uniformity in the nomenclature of materials in wrought iron and steel used in railway work.

It may be as well to observe here that *quenching* is not always considered a means of increasing the hardness of steel.

For, amongst the new steels (which contain other bodies than carbon and iron) some instead of becoming harder by quenching, become easier to work.*

* As the manganese steel and nickel steel.

The German official order says:

"The line of demarcation between bodies susceptible of hardening by quenching, and those are not, being very difficult to determine materials having a tensile strain of 50 kilograms per square millimeter (about 32 tons per square inch) and above, shall be considered steel; materials with a lower tensile strain shall be considered iron" (wrought iron).

Fourth Opinion.—The fourth opinion is one that results exactly from the foregoing lines. It consists in taking as the limit of demarcation between wrought iron and steel arbitrary figure expressing the resistance to tensile strain in kilograms per square millimeter.

This classification is the most artificial of all.

Conclusions.—Not one of these definitions gives a precise meaning to the words iron (*i. e.* wrought iron) and steel, or expresses synthetically the characteristics which distinguish the one product from the other.

Quenching cannot, any more than tensile strain, differentiate iron from steel in cast metal. Quenching always modifies the *deformability* (that is the capacity for undergoing work in the cold state) or the *softness* of the metal; and as regards the tensile strain, that may vary between very large limits according to the temperature at which the test is made.

The distinction between a cast and welded product is the easiest to fix. Such indeed is the opinion of the eminent German metallurgist, Professor A. Ledebur, of the Freiberg School of Mines.

M. Ledebur recognizes that fusion is the characteristic that has been chosen to differentiate *wrought iron* from *steel* not only in America, England, France and other countries (including Sweden and Belgium) but even in Germany itself, where many works bear the name of Stahlwerke (steel works) while at the same time they are making only ingot iron (Flusseisen) which, practically speaking, is incapable of hardening by quenching.

At the International Congress of Engineers held in Chicago in August, 1893, M. Campbell, metallurgist of Steelton, in answer to a remark made by Dr. Wedding, of Berlin, gave his formal opinion in the following set terms of the definition given in 1876 by the International Committee for distinguishing *iron* from *steel*:

"With all due deference and respect for the group of metallurgists who formulated the system used in Germany and recommended for universal adoption, I have always considered this nomenclature as founded on error and impossible to practice." *

To sum up, the second opinion by which a malleable iron product is called by the name of *steel* when it is cast, and by the name of iron (*i. e.* wrought iron) when it is welded * although it only gives an incomplete idea of the properties of each of these two products, remains, all the same, the clearest, the most synthetical, and the one which is almost universally employed.*

Blister steel is cemented iron (*i. e.* wrought iron).

Natural steel is a hard wrought iron not thoroughly refined, like puddled steel. Mechanical work is the means by which it is endeavored to render these products homogeneous.

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* The association of German ironmasters has from the first rejected the definitions relating to iron and steel enunciated in 1876 at Philadelphia by an International Committee of Metallurgists ("Journal of Iron and Steel Institute," 1878, Vol. II, p. 592), definitions according to which the distinction between wrought iron and steel should be ascribed solely to harden by quenching, as has been described above. But after the success of the Basic Bessemer Process in Germany, the said association rescinded its decision for reasons of commercial interest which no longer exist to-day.

A PROPOSED TEST FOR DETECTING BRITTLENESS IN STRUCTURAL STEEL.

By J. P. Snow.

It is felt by many users of structural steel that mill inspectors should give more attention than is now usual to the detection of brittleness in our bridge material. Brittleness may be due to improper heat treatment or to segregated carbon or phosphorus. These defects may occur in material rolled from part of the slabs derived from a given ingot, while material rolled from the same melt, or even from other slabs of the same ingot, may be exceptionally good. If the ordinary tensile and bending tests of the heat from which the material in question is derived should be taken from those parts where objectionable segregation had not occurred and which had received proper heat treatment, the results would not expose the brittle features of the part supposed to be bad.

The desideratum is a practicable method of testing, which will furnish the inspector a means of detecting brittleness in any piece that comes from the rolls that he suspects may be objectionable. The object of this paper is to suggest a scheme which seems to me to answer this requirement.

Prime essentials of a test of this sort are simplicity and quickness of accomplishment. Mill men say, with reason, that they cannot hold stock until machine-finished samples can be prepared and elaborate tests made. I am informed that much of the material now being used is many miles from the mill, on its way to the fabrication shop before the testing-machine work is done on the specimens that are supposed to determine whether the material is to be accepted or rejected.

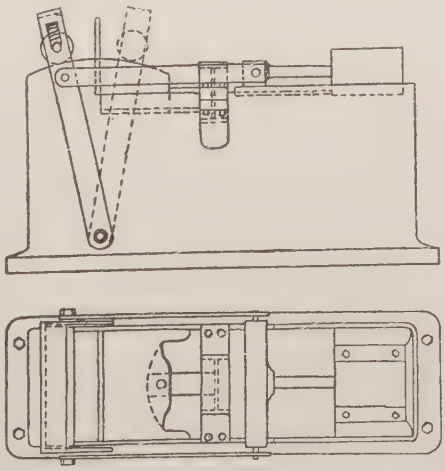
Determining the temperature of the metal after or before the last pass through the rolls is neither efficient, precise nor conclusive. Delaying the piece before the last pass until the right temperature is reached, refines only the outer skin of the material. It is not the function of buyers to tell the manufacturer how he shall produce

his steel or at what temperature he shall roll it, but rather to ascertain if the product which he offers is suitable for their uses. This can be best accomplished by testing the finished product in a direct way.

The scheme herein proposed is in substance a nicked bending test on crop ends of plates and shapes as they are trimmed at the rolling-mill for shipment.

A nicked bend is proposed because the object is not so much to see if the specimen will bend without fracture, as to open up the grain of the steel, to see whether it is fine and silky or coarse and crystalline.

It is proposed to take a generously wide piece of crop end so that the effect of the shear at the edges will not affect the result. It is deemed unfair to the manufacturer to depend upon narrow sheared specimens for this scheme of bending, because the injurious effect of the shear should not be assessed against the quality of the steel. Punched specimens are ruled out for the same reason. If narrow specimens with milled edges or punched specimens with reamed holes are used, the vital element of quickness of accomplishment is lost; for, while the specimens are awaiting their turn at the finishing machine, the plate or shape from which they are cut is loaded for shipment or covered up in a pile of other stock. The scheme proposed will tell its story, if desired, before the rolling heat has left the piece. It can be executed and a decision reached almost as quickly as the surface inspection of a plate can be made.



In detail the scheme is: to shear from the crop end a piece say 12 inches wide and nick it about 3 inches from one edge, preferably across the direction of the rolling, with a tool made for that particular thickness; clamp it in a hydraulic vise and bend the free end over

by power. The sketch shows in outline a possible bending vise. Both the vise and bending roller are to be actuated by hydraulic power, which is always available in a rolling-mill.

The nick is proposed to be made with a tool like a blacksmith's flatter, having a raised bead on its face.

Nicked bending tests by impact have been recommended in the past by many investigators. In 1892 Le Chatelier advocated such tests before the French Committee on Methods of Testing, and since that time work on these lines has been done by Barba, Considere, Le Blant, Aucher, Fremont, Osmond and Charpy in Europe, and by S. Bent Russell and others in this country. All of these experimenters sought to determine the resilience of the material by impact tests; thinking to replace the ordinary tensile tests by these determinations. But as shown in Johnson's Materials of Construction, impact testing is surrounded by so many uncertainties that it has never been found commercially practicable for structural materials. Evidently the constant effort has been to make the test prove too much. In the scheme herein advocated the object is not a complete physical test of the material, but simply an examination of the grain, as shown in the fracture, to ascertain if the material is brittle from any cause.

To insure a fracture in ductile material, the deformation must be localized by a nick. The form of the nick, its depth and shape must be determined by experiment, but for a beginning it is suggested that a depth of $\frac{1}{8}$ the thickness of the specimen be tried; the bead with which the nick is made, to have the form of the Whitworth screw thread. Investigation may show that a single size of nick may be used for different thicknesses, but it is probable that each thickness should have its particular size. The nicking die may be struck by hand hammers, or a light quick-acting steam hammer may be provided for the purpose.

As to the method of producing the deformation it is possible that the distinctive difference between material that is good enough to be accepted and that which ought to be rejected cannot be brought out by making the bend with a press. It may be necessary to use impact, as was done by Fremont in a series of experiments described by him in a paper published by him in Metallurgie in February, 1901, a translation of which by Professor C. L. Crandall, of Cornell University, is appended to this paper. These experi-

ments show that a ductile steel may be broken short off by a blow of sufficient velocity (see Fig. 8). We know that ordinary structural steel when nicked and bent will invariably break unless it is exceptionally ductile and in very narrow specimens; hence, it seems that a press bend on a wide specimen will certainly produce a break and show up the grain. A press bend, if effective, is preferable to a blow on account of its more certain action and because it does not need adjustment for different thicknesses as would be needed if the bending were done by a blow.

It is believed that a test of this kind will expose coarse grain in steel, due to improper heat treatment, segregation, bad chemistry or any defect that tends to brittleness. The engineer may, under present specifications, demand certain chemical and physical qualities when buying steel. He may not be justified in prescribing the exact ratios of the many "ites" or the precise "eutectic values" of the various compounds that enter into the solution which the manufacturer gives him for steel, but he may reasonably demand simple tests like that advocated here to satisfy himself that the material is free from brittleness.

In the past, when puddled iron was the usual structural material, engineers depended largely upon bending tests to ascertain the quality of the output of the mills. Our member, Mr. C. C. Schneider, has told me that he cared little for the tensile strength, elongation and other physical features of wrought iron as determined by the testing machine, but that he set great value on cold bending tests of scrap ends. Sir Benjamin Baker, when engaged upon the Forth bridge, stated that he placed more reliance upon bending tests of mild steel than upon testing-machine determinations. With the steel of the present day we must test for ultimate strength to secure a grade that can safely undergo the ordinary shop manipulations and examine the chemistry to secure uniform composition, but have we not too much lost sight of the valuable old-time feature of bending? The ordinary plain bending will not always show us the grain of the steel. In fact, the width of the specimen and the radius of the bend are so selected in our usual specification that ordinarily good material will bend without fracture. Its ability to do this is the gage for acceptance. To this end the sheared edges are planed, which defeats the very purpose of the test desired on account of the time involved in the operation.

Moreover, we bend but one specimen for each melt, which assuredly does not attempt to control the rolling heat.

It is true that the proposed test may involve closer attendance of the inspector at the mill than our usual commercial testing requires, and it may be impossible to define the lines by which an inspector shall be governed in rejecting material, as sharply as can be done under our present system, but the inspectors' attendance can be arranged for, and the results reached by Fremont give us a clew to what may prove to be a proper criterion for acceptance or rejection.

Referring to Figs. 11 and 12 of Fremont's paper, it will be seen that when a specimen of non-ductile material is bent, a hardened ellipse tends to form on the compression side which acts as a heel around which the fibers on the tension side have to stretch. If the specimen is nicked, this stretch is localized and confined to the fibers at the bottom of the nick and breaking is sure to occur, as is explained in detail by Fremont (Fig. 28). If the material is somewhat ductile and the specimen narrow, the compressed metal flows outward as shown by Fremont's Fig. 11, and explained by Figs. 18 and 19. This flowing out assists compression and tends to decrease the stretch required on the tension side by removing the heel farther from the tension face; and hence helps towards a gradual break instead of a short one. This consideration explains the well-known fact that wide specimens will not bend so successfully as narrow ones.

If, in the proposed nicked bend, the specimen breaks around Fremont's "ellipse of enlargement," instead of square across, or if it does not break clear through, as in Figs. 9, 10 and 13, we may safely conclude that the material is not brittle. If the break is square across and the fracture silky or but partly granular, we may presume that the heat treatment was good and segregation not excessive; but if the fracture shows crystalline facets or appears dull and cokey, it would be ground for rejection. I am sure that workable limits can be fixed for the guidance of inspectors after sufficient careful experimenting. It is possible that thick and thin material cannot be brought to follow the same law, but rules can be established for varying thicknesses. Material that is known to be good and that which is known to be bad, both from overheating and segregation, can be experimented upon and safe extremes established.

Metallurgical literature is filled at present with complaints of poor structure in rails and to some extent in other steels. The complaint is not quite so common in regard to structural steel, for the reason, probably, that it is usually in thin sections, which cool to a lower temperature than thick ones while passing the rolls. It is the case, however, that rolled beams have sometimes proved so brittle and untrustworthy that some engineers dislike to use them in railroad bridges. It is likely that the principal reason for this condition is too high heat during rolling due to their heavy section. If the crop ends of such beams are sheared up so that a section of the web or flange can be nicked and bent in the proposed machine, the coarse structure, if it exists, will surely be exposed and the beam saved from discrediting its species when put into service.

A similar test on crop ends of rails could be made while the rails were passing the straightening press, and many of those having coarse structure at center of head, open grain, lamination, pipes, sulphur flaws, or other defects that one drop test in five heats does not detect, would be saved from going into the track and causing trouble for both user and manufacturer.

The above scheme of testing is submitted for consideration by our members. It is intended to supplement the usual tests for physical qualities, and is suggested as a means of satisfying buyers of steel that their material is sound and free from brittleness. It is cheap in installation and operation, and requires the inspector's continuous attendance at the shearing end of the rolling-mill where he belongs. If properly executed, it should tend to allay the agitation that is now going on among users of rails and structural steel in regard to heat treatment, open grain and other rolling-mill defects. If the scheme is objectionable to manufacturers, it is respectfully offered for their free criticisms.

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*The joint discussion of this paper and the succeeding one on "Tests for Detecting Brittle Steel," by Wm. R. Webster, follows on pp. 272-281. —ED.

APPENDIX.

EXPERIMENTAL STUDIES OF THE CAUSES OF BRITTLENESS OF STEEL.*

By Ch. Fremont.

It has been known for some time that certain irons and steels classed as very satisfactory by tension tests, are not found so in the bending tests upon grooved bars.

A certain metal, tested by tension, had a good elongation, a well pronounced reduction of area, and the area of the diagram which Poncelet calls *résistance vive* of rupture, represented an important number of kilogrammeters.

The same metal, taken under the form of a bar grooved by a saw would break off by bending, following a plane, or nearly so; the volume affected by the deformation would be very small and the resistance vive of rupture would represent only an insignificant number of kilogrammeters.

The brittleness can be sufficiently great to be shown by a test of static bending.

I will take as examples two steels respectively designated under the numbers 9 and 16, and coming from different manufacturies.

Each was tested by tension, in the direction of the fiber in three mechanical laboratories. The results are given below:

Steel No. 9.

	kg	lbs.	kg	lbs.	kg	lbs.
Elastic limit	31.25	(44375)			29.9	(42458)
Ultimate strength	60.3	(85626)	59.35	(84275)	57.2	(81224)
Elongation, per cent.	23.5		23.25		28	
Contraction, per cent.			70			

Steel No. 16.

	kg	lbs.	kg	lbs.	kg	lbs.
Elastic limit	33.25	(47215)			40.7	(57794)
Ultimate strength	60.7	(86194)	59.25	(84135)	57.2	(81224)
Elongation, per cent.	22		19.75		22.20	
Contraction, per cent.			.69			

*Translated from Bul. Soc. A'Encour., Feb., 1901, by C. L. Crandall, Cornell University.

The width of the bars did not permit testing directly crosswise. I have since determined indirectly the resistance crosswise by shearing and at the same time I have verified the resistance lengthwise. I have thus found:

STEEL No. 9.

Lengthwise ..... Resistance in shear 30.31 (43040.)
From which resistance to tension 60.62 (86090).
Crosswise ..... Resistance in shear 28.14 (39958).
From which resistance to tension 56.28 (79917).

STEEL No. 16.

Lengthwise..... Resistance in shear: 29.77 (42333).
From which resistance to tension 59.54 (84665).
Crosswise ..... Resistance in shear: 28.14 (40000).
From which resistance to tension 56.28 (80000).

Fig. 1 is a half-size reduction of the tension diagrams superposed as registered by the machine. The full-size ordinates give the resistances to a scale of 284 kilograms per millimeter (15527 pounds per inch) the full-size abscissas give the elongations, natural size. The full curve corresponds to steel No. 9, the dotted to Steel No. 16.

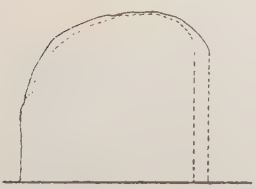
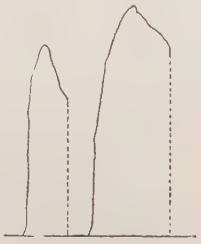


FIG. 1.
TENSION DIAGRAMS.

2 kgm. 3.5 kgm.
FIGS. 2 and 3.



4 kgm. 9.5 kgm.
FIGS. 4 and 5.
BENDING DIAGRAMS.

It is seen that in tension the two steels have a fair elongation for their hardness; their coefficients are quite analogous, with a little more ductility and *résistance vive* for No. 9.

Now let us take the same metals by static bending; the bars are, as are all I have employed, 30 millimeters (1.18″) long by 10 (.4″) wide and 8 (.31″) thick; they are grooved opposite to the impact, by a saw line, 1 mm. (.04″) wide and 1 mm. (.04″) deep.

The Figs. 2 to 5 give the diagrams of bending.

Fig. 2 Steel No. 9 crosswise.
" 3 " " " lengthwise.
" 4 Steel " 16 crosswise.
" 5 " " " lengthwise.

For steel No. 9 the rupture was abrupt, with a small amount of work, 2 kgm. (14.4 foot pounds) crosswise and 3.5 kgm. (25.2 foot pounds)

lengthwise. For steel No. 16 in which the ductility in tension was a little less, the work of rupture by static bending is notably greater; 4 kgm. (28.8 foot pounds) crosswise and 9.5 kgm (68.5 foot pounds) lengthwise. But these are meagre results.

Figure 6 shows a standard of comparison; it is the diagram of static bending of a similar steel, 60 kg (85320 pounds) tensile resistance and 20 per cent. elongation, but not brittle. All things being equal, the rupture is made progressively with an expense of 21 kgm. (151.4 foot pounds). Another similar test piece of the same steel, tested in bending by shock required 23 kgm. (165.8 feet pounds).

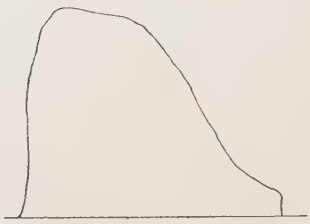


FIG. 6.—Bending Diagram.

The four test pieces crosswise and lengthwise of the two steels Nos. 9 and 16, broken by static bending are shown in Fig 7 magnified $3\frac{1}{2}$ diameters.

One sees immediately as a corollary of these figures, that the rupture produced follows a plane passing in the middle of the groove, and that the volume of the metal concerned and the lateral deformations are small, especially for No. 9.

When the brittleness is not sufficiently apparent in static bending, one may make it evident by having resource to bending by shock. In this case, it is necessary that the height of the fall of the hammer should be sufficiently great. Brittleness shows itself habitually only starting from a certain velocity of impact.

Thus, six grooved test pieces of the same steel and of the same uniform type, marked respectively with the numbers 1, 2, 4, 5, 6, 3, were tested by bending by shock and broken under velocities respectively of 1 meter, (39.37″), 1.10 m. (43.3″), 1.20 m. (47.24″), 1.30 m. (51.18″), 1.40 m. (55.1″) 1.50 m. (59″).

The photographs are shown in Fig. 8. The first five test pieces have undergone deformations differing but little; the sixth, No. 3, alone broke abruptly; the metal had become brittle for a velocity of fall of 1.50 m. (59″); it was not for the less velocities.

To explain these facts, one supposes that the transmission of force is not instantaneous, but depends upon the velocity of impact. The volume of metal affected will depend upon the velocity and diminishes inversely as it. Consequently in the product of resistance by deformation, the factor "deformation," decreases when the velocity of the blow is increased, the product itself diminishes and the rupture takes place with less work.

M. Cornut expressed himself as follows upon this subject in 1889:*

"If we suppose that a piece of steel, iron, etc., is submitted to a continuous effort, slow and progressive, one understands perfectly that

*Etude sur les essais des fers et des aciers.

No. 16

No. 9.

FIG. 7.—Steels Nos. 9 and 16 Broken by Static Bending. (Magnified 3½ diameters.)

this persistent effort is transmitted successively from molecule to molecule, in such a way that all the molecules of the body are sensibly submitted to the same effort. In the case, on the contrary, where the effort is sudden, instantaneous, one understands that all the molecules of the body do not have time to distribute this force, and that the first molecules touched can be torn apart, while the other molecules would sustain no apparent shock.

"Metals can then present very different qualities when they are submitted to slowly applied forces or to suddenly applied ones."

FIG. 8.—Tests with Grooved Specimens at Different Velocities of Impact. (Magnified $1\frac{1}{3}$ diameters.)

In support of this opinion, one may take a well known experimental fact; the influence of velocity upon the results of tension tests. It is known that an increase of speed slightly increases the resistance and slightly diminishes the elongation.

But these variations do not extend far and are not proportional to the speed; tension tests with the aid of explosives furnish figures sufficiently near those of ordinary tests.

Even by bending, with good metals one can find results independent of the speed of the test.

Fig. 9 is the photograph of a test piece marked P (pressure) and tested

by static bending; Fig. 10 is a photograph of a test piece cut from the same metal; it bears the mark C (shock) and has been tested by bending by shock. (Magnified $3\frac{1}{3}$ diameters). In both cases the deformations,

FIG. 9.—Test Piece Broken by Static Bending. (Same material as in Fig. 10.)

FIG. 10.—Test Piece Broken by Shock. (Same material as in Fig. 9.)

which the original parallel lines marked upon the bars before testing, allow of following, are nearly equivalent and the disturbed volume remains nearly the same, in spite of the great difference of velocity in

the two tests. In both cases the amount of work expended was practically the same: 25 kgm. (180.25 ft. pounds).

It is thus shown that the assumed opinion, although it may contain a certain amount of truth, is not sufficient in itself alone. To verify it let us examine the results of experience.

FIG. 11.—Bending Test of Polished Specimen showing Deformation.

Take a piece of steel of any quality, under the same form of grooved bars, and begin to bend it as shown in Fig. 11 (photograph) and 12 (diagram). If the lateral surfaces were sufficiently polished, the deformations would be easily seen. They are formed by the superposition of two elementary deformations, one by depression, the other by enlargement. The depression E F G B H (Fig. 12) is nearly an ellipse in which the major axis coincides with the line A B joining the point of impact with the groove; the enlargement is a portion of an ellipse having the same major axis as the preceding, but the extremities of the major axes do not coincide. These are for the ellipse in depression, the point of impact B and a point placed a little below the groove; for the ellipse in relief the bottom A of the groove and a point placed near that of impact. The two ellipses have a common part A G B H which is itself quite elliptical and in which the deformations by depression and by elevation are superposed and neutralized in part. There results from this that the maximums of deformation may be depression, may be elevation, are localized at the limit of the common ellipse and will be transferred from one part by two anticlinal lines, B G, B H running from the point of impact, from the other part by two synclinal lines, F G, E H starting in the vicinity of the groove. When one continues the bending, rupture naturally follows the weak lines, that is to say the synclinal lines

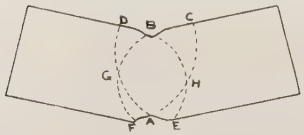


FIG. 12.—Diagram of the deformation shown by Fig. 11.

with progressive stretching along these lines, great reductions of area great expense of work; and finally the lower part of the bar bends with-

FIG. 13 —Character of Break with Non-Brittle Steel.

out rupture; the effort should continue throughout the bending.

It is thus with non-brittle steels of which Fig. 13 is the type.

In the case of very brittle steel (Fig. 14 or 8–3) the enlargement ellipse is reduced almost to nothing; rupture occurs from top to bottom by tension, following the plane which joins the groove with the point of impact; the deformations to the right and left of the plane of rupture are reduced to a small structure throughout nearly all the length; rupture is made abruptly with a very small expenditure of work.

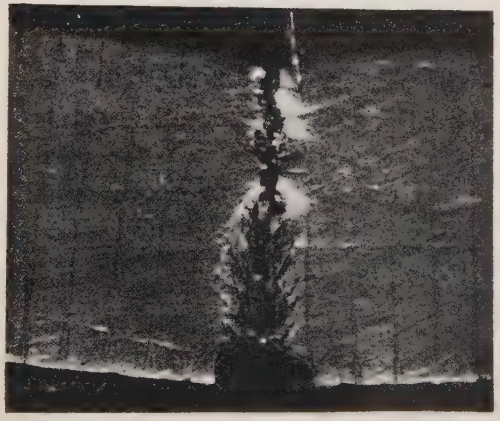


FIG. 14.—Character of Break with Brittle Steel.

For steels of intermediate quality, the phenomena which accompany bending tests are a combination of those which we have found associated in the extreme cases. The enlargement zone C B D G K H (Fig. 15) is stopped at K between the groove and point of impact. Under these conditions, rupture begins by tension, almost as for brittle steels, and continues as far as K. There it meets the anticlinal lines K C, K D and follows one of them or both according as the conditions are more or less symmetrical for the two parts (Figs. 8–1, 8–2, 8–4, 8–5, 8–6). However, as the formation of the anticlinal line in the part H G (Fig. 15) is opposed by the superposition of the depressed zone, it may happen that the rupture will follow the prolongation of A K.; but it will not be as abrupt as for the steels where the enlargement zone is rudimentary.

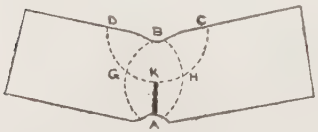


FIG. 15.—Diagram showing deformation of ordinary quality of Steel.

So far we have discussed facts.

For their interpretation we will now cite a simple case.

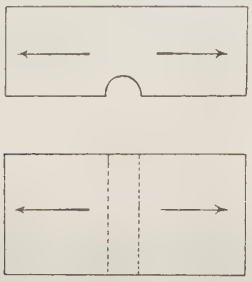


FIG. 16.—Diagram of a grooved test piece under tension.

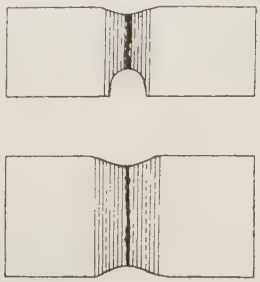


FIG. 17.—Rupture of test piece shown Fig. 16.

If we take a test piece of rectangular section and cut upon one face a semicircular groove (Fig. 16) and then submit it to tension, it is known that it will break in its weakest part in the center of the groove and along a plane perpendicular to the axis (Fig. 17).

A constriction, more pronounced as the metal is more ductile, appears upon the three ungrooved faces, but this stricture will be limited to the width of the groove.

If, in the preceding test piece, the two lateral faces are reinforced opposite the groove by a semi-elliptical enlargement (Fig. 18) and the reinforced test piece submitted to tension, rupture could no longer follow a plane perpendicular to the axis, on account of the supplementary resistance supplied by the enlargement; the deformation will then be around the enlargement and this time we will have two strictures one on each

side of this enlargement; rupture will follow one or the other of these strictures (Fig. 19).

In the bending tests of grooved bars, the artifical enlargement which we have assumed for the tension test piece is naturally produced by the deformation of the compressed zone. And it is seen at once as a consequence of the facts of observation and experience related above, that a steel will be more or less brittle, under determined conditions, according as under these conditions the enlargement zone of the compressed side is more or less small or flat. In other words, the results of the test will depend upon the position of the point K, the vertex of the ellipse of

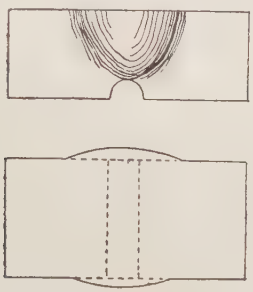


FIG 18.—Diagram of reinforced test piece under tension.

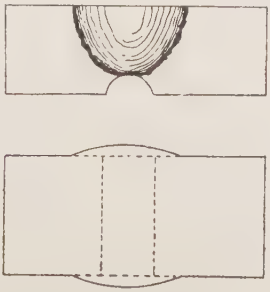
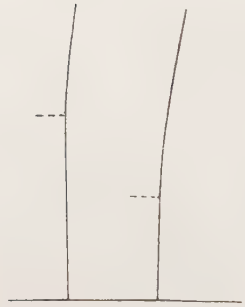


FIG. 19.—Rupture of test piece shown in Fig. 18.

compression (Fig. 15) and of the projection of the enlargement beyond the primitive plane. Should the point K extend as far as A (groove) or beyond, the metal will not be wholly brittle; should the point K remain in the proximity of B, the metal would be extremely brittle; it would be of intermediate quality for the intermediate positions of K. It is useless to add that the projection of the enlargement is of no less importance than its position. All of this seems a flagrant contradiction of the accepted ideas upon the existence and position of the neutral fibers which are considered as forming a plane parallel to the compression and tension faces of the test piece and equally distant from them. It is true that these ideas cannot be extended indefinitely beyond the elastic limit. But it is certain from the observation of facts that in the limits of permanent deformations, the surface of the neutral fibers is neither parallel to, nor equally distant from the faces. The areas of depression and extension are not limited; they intersect and the surface of the neutral fibers is the locus of the points where the depression is equal to the elevation. As to the position of this surface, it can vary with the conditions of the test, and other things equal, it varies with the quality of the metal.

We will then put our conclusions in a new form and say. The nearer the neutral fibers approach the compression face, the more brittle the steel; and reciprocally, the nearer the neutral fibers to the tension face, the less brittle the steel.

The fact that the neutral surface is not, or cannot be, at equal distances from the compression and tension faces of the bar submitted to bending, clashes with another accepted idea, that of the equality between the elastic limits of compression and tension. But these are the facts. We have just seen that with brittle steels, the zone enlarged by compression remains confined to the vicinity of the impact and presents only a very small projection; in tough steels on the contrary, the zone enlarged by compression extends to the vicinity of the groove, and makes a projection in consequence.



FIGS. 20 and 21.—Compressed diagrams of steels Nos. 9 and 16.

I have tried to verify experimentally the resistance of greater or less differences between the elastic limits of tension and compression. I have determined the elastic limit in compression of the two steels No. 9 and No. 16, for which I have given above the elastic limits in tension from two different laboratories. As the apparatus which I used in my own laboratory was not designed for this sort of work, I could not count upon very great precision. Nevertheless, the diagrams of Figs. 20 and 21 executed with care have given me the figures which are certainly exact to about 1 kg. per mm. (1,419 pounds per in.) I find thus 41.60 kg. (59,146 pounds) for the elastic limit in compression for Nos. 9 and 23,40 kg. (33,282 pounds) for that of No. 16. One recalls that the elastic limits in tension were respectively 29.90 kg. (42,505 pounds) and 31.25 kg. (44,440 pouuds), a mean of 30.55 kg. (43,408 pounds) for No. 9 and 33.25 kg. (47,278 pounds) and 40.70 kg. (57,856 pounds), a mean of 37 kg. (52,632 pounds) for No. 16. One sees that for No. 9 the elastic limit in compression is much greater than the elastic limit in tension; the metal is very brittle. For No. 16 the difference is in the other direction, even if one chooses the smaller value of the two (rather divergent results) found for the elastic limit in tension; this metal is not so brittle as the other, while still being far from ideal.

Following the same line I have borrowed from H. Hadfield* the results of his experiments, on the series of alloys of iron and nickel. The elastic limits of tension and compression are brought together in two columns.

Without having very precise data upon the brittleness of this series, one knows in a general way, that with forged bars, the alloys with a small amount of nickel are not brittle, that the brittleness appears with a sufficient amount, passes through a maximum at about 14 per cent.

*Proceed. Inst. Civ. Eng.

and disappears at about 27 per cent. The sign and amount of the differences between the two elastic limits agree well with these data.

I have been led to express my conclusions in a paper recently presented at the Academy of Sciences * saying that a steel is brittle (that is to say breaks abruptly in bending with a small expenditure of work) or not brittle (that is to say breaks progressively, requiring an amount of work proportional to that required for rupture by tension) according as the ratio of the elastic limit in tension to that in compression is less or greater than unity.

However, this simple form is probably too absolute, because the elastic limits determined under ordinary conditions of static tests are

MECHANICAL TESTS BY H. HADFIELD UPON THE ALLOYS IRON-NICKEL.†

	Chemical Composition			Elastic limits in compression	Tension tests			
	C	Mn	Ni		Elastic limit	Rupture	Elongation per cent.	
A	0.19	0.79	0.27	22	19	31	35	
B	0.14	0.75	0.51	22	20	30	36	
C	0.13	0.72	0.95	20	25	23	31	not brittle
D	0.14	0.72	1.92	27	26	34	33	
E	0.19	0 65	3.82	28	28	37	30	
F	0.18	0.65	5.81	40	28	41	27	
G	0.17	0.68	7.65	40	31	49	26	
H	0.16	0.86	9.51	70	42	85	9	
I	0.18	0.93	11.39	100	65	94	12	very brittle
J	0.23	0.93	15.48	80	55	94	3	
K	0.19	0.93	19.64	80	47	71	7	
L	0.16	1.00	24.51	50	32	77	13	
M	0.14	0.86	29.07	20	25	38	33	not brittle

not exactly applicable in the case of tests by shock and upon grooved bars. It is sufficient to say, in order not to exceed the results found by experience, that a steel is or is not brittle according as its capacity for deformation by compression exceeds or not its capacity for deformation by tension under the conditions of the test. The static elastic limits certainly form one of the factors in play but not the only one.

We are now led to seek the experimental conditions necessary to show the amount of brittleness.

From what we have just seen, all possible artifices capable of revealing brittleness always lead to one of the following: to restrain the compression, or to favor the tension.

*T. CXXXII p. 202, Jan. 28, 1901.

†Proceedings of the Inst. of Civ. Engrs. Vol. CXXXVIII London, 1898–1899.

For example, if one places a hard slightly deformable block in the compression side of a bar of non-fragile steel (Fig. 22) the metal will break by tension, with a small amount of work; it has become brittle.

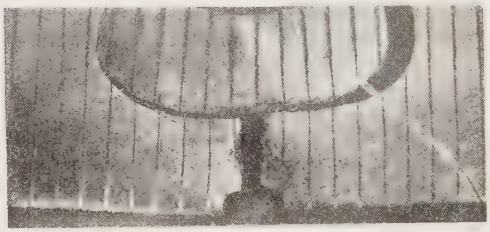


FIG. 22.—Character of Break when Hard Block is inserted in Compression Side.

The role of the grooves is easily explained. (I do not speak of their form, which will be the subject of another paper.) The grooved test piece (Fig. 23) can be considered as the sum of a series of elementary plates, a, b, c, d, etc., which will be submitted successively to tension; but the first test piece a, the weakest, will have a very restricted elongation, limited as a maximum to the width of the groove; if, then, the deformation by compression extends only as far as the groove to reinforce the opposite metal, this first test piece will break as we have just seen along a plane passing through the middle of the groove; the greatest effort which determines rupture is concentrated upon a section so much diminished, and the break will spread instantaneously until it is arrested by the enlargement due to compression, if this enlargement has been able to form. In fact the groove has favored rupture by tension.

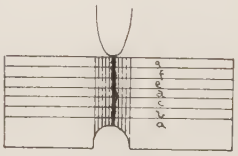


FIG. 23.—Diagram of rupture of grooved specimen of brittle steel.

In the absence of the groove, the elongation of the first elementary test piece is not localized; but it may extend over the whole face. Here again, the metal would be brittle if the deformability by compression is relatively small, the greatest part of the total deformation is due to tension; but the conditions are the worst possible to bring out brittleness.

To explain the influence of the velocity of the shock, one may assume the current idea, that is to say, the diminution of the disturbed volume is proportional to the increase of the velocity of impact; the zone raised up by compression is also decreased; but for this influence or effect it is necessary that the metal may be near a certain point of passage, in order that small variations may displace the surface of the neutral fibers. *If the metal is very good or very poor, its properties are too marked for the role of speed to manifest itself.*

By induction from proved facts, I foresee if such predictions are permitted, that other influences, known factors of brittleness, will some day be explained by the relative variations of deformability in tension and compression; thus the effect of the cold, that of work at a blue-heat, that of vibrations and fatigue

These experiments show that the tests by tension alone, or the tests by compression alone, do not define a steel. Both tests are necessary, and flexure which unites them is a complete method of testing, on condition that one gives to it by well chosen devices the proper sensitiveness, neither too great (all steels appear brittle) nor too small (brittleness disappears). This can be obtained by grooves of appropriate forms and dimensions.

TESTS FOR DETECTING BRITTLE STEEL.

By William R. Webster.

All engineers aim to avoid the use of brittle steel in their structures. They have, very properly, specified such chemical limits as will eliminate this trouble in steel from segregation. This course has been followed in this country for years and does not need further comment.

Most of the steel now made will meet all the requirements of the specifications in general use, with a large margin to spare. This has given a false sense of security and too many chances are being taken. In some cases the cold bending tests have been omitted on boiler steel and the material accepted on the results of tension tests alone. Hundreds of boilers are made every year under these conditions. Every now and then a plate fails in shop work and samples taken from such plates will generally not bend flat cold, or anywhere near it. We have no means of learning how many other brittle plates, which do not fail in shop work, are put in boilers. The failures generally occur in thick material, and in most cases the ordinary cold bending test as called for in our specifications would have detected the brittleness.

There are other cases where axles, rails, etc., are put in service without any physical tests whatever. This is directly contrary to the specifications adopted by this Society and the opinions expressed in the discussions at our meetings.

Some think that heat always has a softening effect on steel, as in annealing, and that the hotter the steel is finished in rolling or forging, the softer it will be. On the contrary, under such conditions, heat has a hardening effect and is one cause of brittle steel. The laboratory experiments on the effect of heat have been confirmed by the results obtained from large masses of steel. Steel finished too hot in rolling or forging will have a large grain and will fail under the ordinary cold bending and drop tests. The engineer cannot ignore this any more than he could ignore the effect of

chemical composition. Under these conditions is it not proper and just that he demand of the maker some assurance that his steel is finished at the proper temperature and not at any temperature? It is, of course, preferable to prevent, if possible, steel being made brittle, than to take the chances of its being detected after it has been made brittle.

This Society took a decided step in the right direction in specifying that cold bends shall be made on each heat of steel in the condition it leaves the rolls. This has been more clearly defined by the Committee on Iron and Steel Structures of the American Railway Engineering and Maintenance of Way Association, in their specifications, as follows:

> "Full-sized material for eye-bars and other material one inch thick and over, tested as rolled, shall bend cold 180° around a pin the diameter of which is equal to twice the thickness of the bar without fracture on outside of bend."

This requirement has been put in general use and necessitates the bars being finished in rolling at a lower temperature, and large eye-bars are now made which meet the requirements of full-sized tests, very much better than formerly.

All of our present specifications make concessions in the requirements for the heavy material, and it is a question if we have not gone too far in that direction, as it assumes that such heavy material will, of necessity, be finished at a much higher temperature than the lighter material. It also does not induce the maker to improve his methods. The necessary improvement in the present methods which would be required to finish the heavy material at the proper temperature would decrease output and increase cost of such heavy material. Is the consumer willing to pay more for a better material? If so, the maker would, no doubt, meet him half way.

It will not be necessary to adopt any of the more elaborate tests which have been suggested to detect brittle steel, if the finishing temperature is properly controlled and wide cold bends are made of the full thickness of the material as rolled. But in the case of forgings, castings, and other very heavy material, annealing will have to be more generally introduced.

DISCUSSION.*

Mr. Kent.

WM. KENT.—That brings me back to ancient history again. When I was at Shoenbergers we had many kinds of tests. We had a test of bending a cold sample of the piece of plate, and then hammering it down flat.

At one time I was called on to report on the Sherman process; some of you may remember that process. It was claimed to improve the quality of open-hearth steel, and the promoter said, "You take your tank-steel stock and make it as good as boiler plate by putting in a little physic." We were then making several grades of steel, one boiler and fire-box, and the other tank steel, higher in phosphorus. In testing the Sherman process we arranged that there should be six heats made of our regular tank steel, and six other heats precisely like the first by the Sherman process, physic added. We found there was no difference between the two lots. The crucial test was the cold test. Plates 5-16 in. thick and 12 in. square were flanged over flat and bent down flat under the hammer, and the bent piece bent double again. Every piece of boiler-plate steel stood that test perfectly, but not a single piece of the tank steel either made ordinarily or by the Sherman process stood that test, but broke either in the first or in the second bend. So that was a complete proof that the Sherman-process steel was not as good as boiler-plate steel, and for this purpose the bending test was better than the tensile test.

We found that boiler-plate steel was invariably lower in tensile strength than tank steel of the same carbon, and so much so that a plotted field showing the relation of strength to carbon in tank steel lay entirely above and outside of the field covered by the boiler-plate steel. I am very glad to hear this paper on cold bending, and I hope the steel men will take this matter up and let us know more about it next year.

Mr. Sauveur.

ALBERT SAUVEUR.—I was glad to hear that Mr. Snow favors the nick test. I think there is a very great deal to be said in favor of

*Joint discussion of the two preceding papers, viz.: "A Proposed Test for Detecting Brittleness in Structural Steel," by J. P. Snow, and "Tests for Detecting Brittle Steel," by Wm. R. Webster.—ED.

it. It is employed quite largely abroad by the French and German railways, but it does not seem to me that it has received the attention it deserves from American engineers. The shortcomings of the ordinary tensile test is known to all of us. We know that very frequently metals which when subjected to the tensile tests had proved satisfactory, fail in service, and when we come to test pieces cut from the broken pieces very frequently also we find the metal apparently ductile. It seems to me that there is a certain particular brittleness which escapes the tensile test, and it is this kind of brittleness that is better revealed by the nick test. I think those of you who read the many papers written by French engineers on the nick test must come to the conclusion that it deserves more attention than we have given to it so far. Mr. Sauveur.

I was also glad to see both Mr. Snow and Mr. Webster emphasize the importance of heat treatment. I think we are now all of one mind on this question. The difficulty is to find a suitable test that will control this heat treatment. It would seem at first as though the microscope might be the most promising way of doing it, and undoubtedly it can be improved in that direction. The difficulty of introducing a determination of structure in specifications it seems to me is very much of the same character as the difficulty which we meet when we desire to introduce the amount of combined carbon in cast iron specifications. We all know that we really don't care for silicon, and yet it is the amount of silicon which is specified because of its influence on combined carbon. In none of the specifications do we require a certain per cent. of combined carbon, always depending for that upon the silicon present. In the case of the micro-structure we are in a very similar position. Take a cross section of a large steel implement, and the grain is so much affected by the rate of cooling that it is a matter of great difficulty to devise a suitable micro-test. If we take the structure in the center, we find it is much coarser than on the outside. Like the proportions of combined carbon in cast iron, the micro-structure of steel is greatly affected by the rate of cooling.

J. A. KINKEAD.—In nick-bending there is another feature to be considered, namely, the right temperature of the piece. In making nick-bending tests of fire-box steel, on $\frac{1}{2}$-in. or thicker material, it is rather difficult to get the desired fracture unless Mr. Kinkead.

Mr. Kinkead. the piece is heated slightly, say to 125°. If tested cold it will break off short.

Mr. Bostwick. W. A. BOSTWICK.—It seems to me a word or two ought to be spoken as to the manufacturer. We have heard quite a good deal about what the user wants, and that the manufacturer needs to meet the user and so on. As a matter of fact, the manufacturer does more than meet the user half-way. As an illustration of the necessity of regulating the heat treatment, so often referred to, the rolling of large eye-bar flats is a good example. The normal product of a mill rolling this class of material has been curtailed 30 per cent. to secure material that will be satisfactory in every respect. The manufacturer is ready and willing to do anything within reason, but we must not lose sight of commercial considerations. These propositions advanced here to-day, such tests as examination of the micro-structure of rolled structural material, and the making of the nick-bending tests are in my estimation not commercial. Suppose a case, for example, where we have to make nick-bending test for every bar of material rolled. We might have a large order at a plant placed around at half a dozen different mills being executed at the same time. It is readily seen that an army of inspectors would be required to pass material, and I am satisfied the user would get no better results from the manufacturers than he does now. At present consumers are not rushed for material, but it was not long ago that material was urgently called for and the question of quick shipment was of the utmost consideration. I think, therefore, that we should not advocate doing anything that is going to depart from commercial considerations in any respect. While micro-structure is an important thing in steel inspection, the test specimen requires considerable time in preparation, and time that will seriously impede the operation of the materials and the shipment of the finished product.

Mr. Campbell. H. H. CAMPBELL.—The micro-structure test is not practical; it takes too long. Rapid inspection is necessary and is better for the consumer and for the manufacturer. The statement that every bar should be tested is unreasonable. There are arguments for it just as there would be for testing both ends of every bar, for one end may be overheated while the other may be too cold.

Mr. Christie. JAMES CHRISTIE.—It would be very desirable to have a quick and inexpensive but satisfactory method of testing the material

as it is rolled in the mill. Such a result, if procurable, would save frequent expense and delay; also considerable friction between the producer and the consumer. Mr. Christie.

There will be found in the proceedings of the Society of Civil Engineers for 1893 a paper read by the late Alfred W. Hunt, at the Engineering Congress in Chicago, proposing a method of testing by the recorded resistance and the work done in punching the metal. During the discussion, I suggested to Mr. Hunt that he carry his proposed system a little further, and instead of relying on the punching test alone, to use a combined punching and drifting test.

The suggestion was to form a tapered cone above the punch and use a segmental opening die. When the perforation was effected by the punch, the tapered shank behind it would follow up and drift or enlarge the diameter of the punched hole. The operation would be performed on a machine and the resistance and work done, both in punching and drifting, would be accurately recorded. It would apparently be quite feasible to perform this operation on the crop end of every bar that was rolled, if desired, with little expense and no waste of valuable material.

J. J. SHUMAN.—There is no doubt that an occasional lot of steel goes on the market and into important structures that is not just what it ought to be, although tensile tests have been made on it. I suppose a test such as Mr. Snow proposes would be a good one, but after several years' observation of the methods of inspectors I feel sure that it assumes too much intelligence on their part. While I am glad to say that I have met many bright men among the inspectors, I regret to add that I have also seen too many of the other kind. It is too bad that steel manufacturers should be at the mercy of young men of insufficient experience, working under iron-clad rules, and whose say-so can cost a manufacturer a great deal. It would be very desirable if some reasonable method could be devised whereby a man of only ordinary intelligence could determine whether steel is brittle or ductile. It may be, after all, that the maker himself can be relied on to work out the problem by original research. If brittle steel does go out of his mill he generally hears of it, and he hears from it in enough cases to set him to thinking and working. It will not need a difficult, tedious test such as is proposed to deter- Mr. Shuman.

Mr. Shuman. mine this. I think the steel makers are working out the problem. There is much less steel spoiled by hot rolling now than there used to be, and I think we are all working in the same direction, and may be depended on to turn out steel that is thoroughly suitable for the work for which it is inteded.

Mr. Metcalf. WM. METCALF.—I don't want to take up the question of heat treatment, but I want to say a few words and will tell a story about inspection. We were inspecting 10-in. shells, and the inspector had a hammer with a sharp steel point. He would examine the shells and occasionally he would find a shell with a rough surface and he would hammer it roughly in an effort to reject it. There were two rings to try over the shells to test the outside diameter. It was my custom always to stand opposite the inspector, and use one ring to help him. Presently along came a shell that was a beauty. It was burnished and polished bright, perfectly round in every way. The officer looked at it, examined it and rolled it over to me, and I rolled it off behind me. After throwing out about twenty shells in that way he stopped and looked at me. He said, "I don't like this. I am sent here by the Government to inspect these projectiles under certain regulations. I find a shell all that it ought to be and pass it along and you throw it out, and it doesn't seem to me fair to the manufacturer when a shell passes my inspection to throw it out. It seems to me you ought not to do it." He said, "My inspection is sufficient and my orders are peremptory." When he got through, I said, "I will tell you that I have orders quite as peremptory as your own, and perhaps more important, to me at least, from the fact that if I break them I will be kicked out very promptly. My orders are to see that under no circumstances either a defective gun or projectile shall go from this place, and my business is to see that they don't do it. These shells I have thrown out are perfectly worthless and extremely dangerous, but you can't find it out because you don't know how." The next time another one came along I said, "Now look at this shell. There are little holes there about as big as a pin head, or rather as big as the point of a pin," and I said, "Hit one of them with your hammer." He finally hit a hole and it closed up, and he said, "That's nothing." I said, "You don't know how to use a hammer, and that hole is open instead of closed." I took a pin and put it into half a dozen or more holes, in some cases down

to the head of the pin, and I said, "If you send them out to your friends in the field the shells will be fired, and will burst in the gun and perhaps kill a lot of our own men." I said, "Throw away your hammer." He said, "I must have it." "Well," I said, "if you must have it, keep it, but don't use it here." The result of it was that in a very short time he became exceedingly expert, and he became a life-long friend of mine. He was afterwards General Flagler, Chief of Ordnance. Mr. Metcalf.

I want to say in regard to the papers of Mr. Snow and Mr. Webster, that so far as I know anything about steel, I am exceedingly well pleased with the good sense of the papers; only I would suggest to Mr. Snow that if he is going to use the nick test, he should be very careful to have an exceedingly sharp edge, so that when he makes a nick in the steel it will not compress it. With a dull edge you press the grain and change the structure of the steel entirely under the nick. That is extremely important. I think the microscope will bear me out. You must cut the nick and not punch it.

In regard to the grain, a great deal has been said about coarse grain. It sometimes is possible, in fact it is very possible, to have an exceedingly fine grain with a very brittle piece of steel. Another feature I think should be tested, and that is, to see that you have no fiery steel. I say fiery because it expresses it better than anything else I can say. It is a sure indication that that piece of steel has been too hot, too hot all the way through, and it may be still exceedingly fine in the grain. They should know not only the size of the grain, but the color. The color is all important in the structure of steel. It is quite as important as structure.

As to what Mr. Campbell said about the necessity of testing both ends of a bar, I agree with him fully. In the manufacture of tool steel it is absolutely necessary, because you can make a piece perfect at one end and very fiery at the other, and at one end you have cast iron instead of steel and the fiery condition of the steel shows that condition very nicely.

In regard to cold rolling, I am sure Mr. Campbell will bear me out, he knows as well as I that if you roll a piece too cold and break it open, you are apt to find a center that is quite black. It looks as if all the carbon in the steel had been concentrated and driven into the center. The fact is that by rolling it too cold the

Mr. Metcalf. rolls have crushed the grain of the steel, although in tool steel a piece that has grain may be worked into a tool and hardened beautifully. When you temper it, as soon as it reaches the ordinary temper color, you find the hardness has gone, and that that crushing has in some way affected the carbon, I believe it has thrown it out by too cold rolling.

It is a very easy thing for the roller to roll the steel too hot and leave a coarse and very fiery grain, and when you come to temper it, the temper is all drawn out. On one occasion the roller had been instructed to hold back the steel until it was deep orange red, and I noticed one day that he was holding it back, not quite back to the dark color, but to what is called medium orange color. I remonstrated with him and said, "You are not getting that right." He said, "Yes, we are. We followed your instructions implicitly, and when it got too low the grain remained rather coarse and fiery, but taking it at the right temperature you can arrange it very nicely, and it comes out a steel blue." I examined a great many pieces and found that he was right, and the reason was that when they got to the point where they held the steel back to let it cool to the right temperature there was not much work to be done in making the finished bar, and when they held the steel down until it was a little too low it crystallized and hardened so that in passingthrough the rolls the pressure was not sufficient to change the grain, and the steel remained coarse and fiery.

Mr. Fay. HENRY FAY.—I have noticed during the last few years some phenomena in regard to the heat treatment of steel which appear to be contrary to some of the established facts. It is granted that the best way to finish a piece of steel is to work it down to the lower critical temperature, that is to about 700° C. This produces the finest possible grain which is so highly desirable. If, however, we reheat a piece of steel which has been subjected to this treatment we get a series of different structures depending upon the temperature and time of reheating. Simply treating again to 700° is likely to change this fine-grained structure into a coarser structure, and if a very high temperature is reached the structure is very much coarsened. In reheating a series of bars of varying composition I found that refinement of the grain invariably takes place before the very coarse structure is produced and that this fine structure is produced on reheating to about 800°. In

other words, if we start with a piece of steel which has had its fine-grained structure produced by working to the lower critical temperature, this same fine-grained structure will be maintained only when reheated to about 800°. The exact temperature will of course depend upon the composition and rate of heating. In some nearly pure iron, some steel tubing containing .07 per cent. carbon, this temperature was 890°; in some steel containing 0.3 per cent. carbon and 0.6 per cent. manganese the temperature was near 800°. In other cases this same phenomena was noticed. It seems to me that this refinement of the grain has some close connection with the temperature at which free diffusion of the various elements takes place, and there is some work now in progress in which it is hoped to verify this assumption. In the annealing of steel plates this is of considerable importance, since reheating to the critical temperature is not sufficient, but for each steel we must know the temperature to which it is necessary to reheat. Mr. Fay.

In regard to Mr. Metcalf's statement as to cold rolling, I had an experience several years ago with a piece of steel which was turned over to me in which there was a very serious segregation of phosphorus. The segregation took place about midway between the center, and on the outside of a $3\frac{1}{2}$-in. bar; on the outside there was about .07 per cent. of phosphorus, and in the center segregated portion about .19 per cent., showing that the phosphorus had been rolled from the outside material or had flowed from the center. Whether this was caused by cold rolling or by the fact that the outside of the bar had been heated to a high temperature and the heat had not penetrated the center, I am unable to say, but at any rate the piece was very interesting because it showed a very serious segregation.

J. P. SNOW.—One of the several weak points in my paper is the proposed manner of making the nick with a compression tool, as it might be called. I supposed some one would pick me up on it, because I objected to the use of the punch and shear on account of their tendency to injure the material by their compressive action. The method of nicking which I advocate is practically the same thing, but I put it forth because it is so quickly and cheaply executed, and I hope that it will be efficient. I am not sure, in spite of all the talk we have had, but what the test may be effective and Mr. Snow.

Mr. Snow. efficient for the purposes for which it is intended. We don't expect these specimens to bend without breaking. What we want them to do is to break, but we don't want the tool to affect the material so as to disguise its proper nature. If it is impossible to make the nick with a chisel so it will break properly, we must make it with a cutting tool. The objection to the cutting tool, is the fact that it takes more time to use it than the chisel which I described; but perhaps this objection could be overcome if necessary.

Another weak point is the one that Mr. Schuman brought up, about the danger of the inspector rejecting material which he ought not to. I realized and so stated in the paper that it might be difficult to define the exact limits which should govern the inspector in accepting or rejecting material. It may not be necessary to depend on an inspector for a decision. I for one, as a buyer of steel, am willing to leave that to the manufacturer and have the inspector there simply as a check. If he will send me a description of the fracture, I will risk the manufacturer to reject the material if it is very bad. I have a great deal more faith in the manufacturers than some seem to have, and I don't believe they intend to send out poor material. They cannot tell a bad beam, for instance, from a good one, simply by looking at the outside; I think they ought to see the grain. There is a necessity for it, and I believe some such test as I have advocated will enable them to see it. If it had fiery grain and entirely poor structure inside, I am sure they would not send it out to their customers.

Mr. Webster. W. R. WEBSTER.—I should like as a matter of record to call attention to a recent paper by Professor Unwin. He advocates more requirements in the tension test, and the abandonment of the bending test. That is just the opposite of what is advocated here. The trouble at the present time is that often no bending tests are made, and when they are made on specimens they fail to give correct information. If bending tests are made on pieces of the full thickness of the material they will often show the brittleness revealed by the nick test.

Mr. Schneider. C. C. SCHNEIDER.—I have made a large number of bending tests on full-sized eye-bar flats of various sizes. These tests have proved to be one of the most convenient methods of detecting brittle material; they are not expensive to the manufacturer and can be readily made at the mill without delay. These full-sized

tests can be made in less time and with less labor and expense than is involved in the preparation of *specimens* for bending tests. Full-sized bending tests are prescribed in the specifications adopted by the American Railway Engineering and Maintenance of Way Association, and should, in my opinion, also be incorporated in the revised specifications of this Society. Mr. Schneider.

THE PRESIDENT.—It is well known, I think, that the method of producing a fracture has an influence on the appearance of the fracture, after it is produced. A slow-moving test which results in fracture is generally more or less silky, while a break produced by a blow or a shock is generally granular. Is it possible that we may deceive ourselves by laying too much stress on the appearance of the fracture, and is it not necessary that we should have knowledge of how the fracture was produced, in order that we may draw any safe conclusions from the fracture? The President.

M. H. WICKHORST.—I should like to say a word about the character of the fracture. In making tests of boiler plate by the nick-bending test to note whether laminations are present, nicking the material slightly and bending it over may give a fibrous fracture; while nicking it deeply and breaking it off may give a crystalline fracture for the same test piece. Mr. Wickhorst.

MR. SNOW.—I should like to refer again to the paper of Mr. Fremont. He showed that a very ductile steel can be broken off short by a blow after it has been nicked if the blow is of sufficient velocity. He showed a series of specimens cut from the same bar, some of which bent over without fracture and others which broke short off. I have called attention to that paper as much as possible, and I hope those interested in the matter will look over Mr. Fremont's paper thoroughly after it is published. It will be found to throw light on several points that have been spoken of here. Mr. Snow.

TENSILE IMPACT TESTS OF METALS.

By W. Kendrick Hatt.

Introduction.—In 1894 appeared Professor Merriman's interesting account* of the state of knowledge concerning the capacity of metals to withstand suddenly applied loads.

The author of the present paper was stimulated thereby to investigate the relative behavior of materials under impact and gradual loading. As the greater part of our present knowledge of the mechanical properties of materials is based on the results of tension tests under gradual loading, it seemed that the most direct comparison would result from tests in tensile impact. A vertical tensile impact testing machine was therefore constructed in 1897 and, since that year, experiments have been carried on in the Laboratory for Testing Materials of Purdue University, with the aid of a number of students whose patient and faithful services the writer here desires to acknowledge.† Other matters of a more or less practical interest have of late engaged the author's attention to the exclusion of these experiments. He is, however, loath to abandon this field without recording part of the results of the investigation, which, while incomplete, are nevertheless

* "The Resistance of Metals Under Impact"—Mansfield Merriman, Proceedings American Association for the Advancement of Science, Vol. 43, 1894.

† The experiments form the subject-matter of the following undergraduate theses:

"Tests of Steel and Iron Rods Under Gradual and Impact Loading." L. V. Ludy and F. Nulsen. 1898.

"A Study of the Behavior of Metals Under Impact." J. T. Nichols, J. W. Raub and T. G. Knauss. 1899.

"Effect of Temperature on the Resistance of Iron and Steel to Impact." W. E. Jewell and G. S. Eaton. 1900.

"A Study of the Resistance of Iron and Steel Under Impact." O. Klipsch and C. S. Johnson. 1901.

"A Study of the Shock-Resisting Properties of Steel Castings." J. S. Tatman and N. J. Wheeler. 1902.

fairly definite in their indications. The results are interesting and may prove of use as a basis of correct thinking in relation to a matter which must have aroused the curiosity of many engineers who are concerned with the use of the materials of construction, and who have wondered if the static or gradual tests, now so universally used, give evidence of properties which fit a metal to withstand impact conditions.

The results described below lead to the conclusion that the ductility and shock-resisting capacity of metals of normal quality are not less under impact loading than those disclosed by the static test. If the tests had been continued to include materials that had proven defective in service, evidence would no doubt have been obtained to determine whether or not some form other than the static test is necessary to detect these defects. It should be noted that the speed of rupture of these tests corresponded to rupturing a tension bar that stretched 2 inches in one one-hundredth of a second, or 16.6 feet per second, a speed much below the critical speed of transmission of stress in steel, *i. e.* 17,600 feet per second.

Recent work in Germany and France points to the conclusion that some form of impact test is found necessary to detect faults of structure that are not evidenced by the static test. It now appears that flexural impact test upon a nicked test bar is the best instrument for this purpose. The many mechanical difficulties inherent in the tensile impact test should, in the writer's view, prevent its use, especially in view of the fact that the flexural test is adequate to the purpose.*

DEFINITIONS.—The term "rupture-work" is taken to mean the work done in deforming a body to rupture. The area between the ordinary stress-strain diagram and the axis of deformations is a measure of this rupture-work. The latter term has often been

* For an account of the state of knowledge relating to impact tests and for a bibliography of literature, reference is made to the following:

American Section, International Association for Testing Materials.—Bulletin No. 5, October, 1899. Report of Committee on Present State of Knowledge Concerning Impact Tests.—W. K. Hatt and Edgar Marburg.

Bibliography on Impact Tests and Impact Testing Machines.—Proceedings American Society for Testing Materials, Vol. II, page 283.—W. K. Hatt and Edgar Marburg.

TABLE II.—SHOWING COMPARATIVE TESTS UNDER GRADUAL AND IMPACT LOADING IN TENSION.

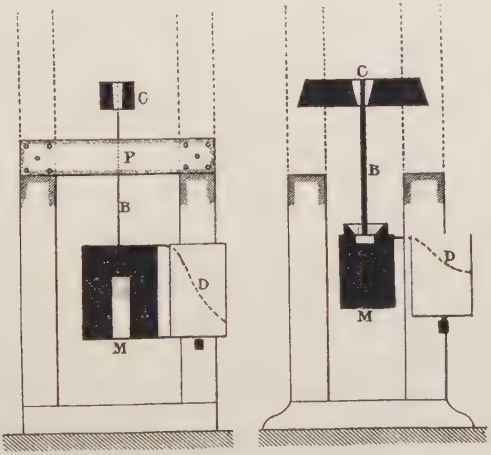
No. of test.	Material.	Dia. ins.	Gage l'gth, ins.	Ultimate strength, lbs. per sq. in.	No. tested.	Elongation, Per cent.			Rupture-work, ft.-lbs. per cu. in.			Kind of test.	Gradual Loading Referred to Impact Loading as Unity.					
						Max.	Min.	Aver.	Max.	Min.	Aver.		Elongation,			Rupture-work,		
													Max.	Min.	Aver.	Max.	Min.	Aver.
1	Steel wire	0.16	48	115,000	2	0.71	0.48	0.59	144	130	136	Gradual	0.71	1.14	0.84	0.67	0.78	0.74
			108		4	1.00	0.42	0.70	208	165	186	Impact						
2	Steel wire, annealed	0.16	48	83,000	1			9.30			566	Gradual			1.33			1.04
			108		5	11.00	8.70	9.80	803	648	772	Impact						
3	Steel wire	0.30	48	71,800	2	8.00	6.00	7.00	554	534	544	Impact						
			108		6	15.60	12.00	13.60	903	515	765	Gradual	1.00	1.07	1.04	0.95	1.34	0.96
4	Steel wire	0.26	108	109,000	2	4.64	4.62	4.63	349	347	348	Impact						
			108		15	7.00	4.00	5.10	699	443	556	Gradual	0.66	0.92	0.79	0.51	0.58	0.55
			69		5	7.00	5.00	5.80	673	596	626	Impact						
5	Nickel steel	0.50	8	85,000	6	26.70	22.10	23.60	1,505	1,360	1,414	Gradual	0.90	1.06	0.98	0.67	1.13	0.77
6	Soft steel		8	68,000	8	29.40	20.70	24.00	2,216	1,203	1,821	Impact						
			8		7	26.30	21.90	23.90	1,532	1,260	1,376	Gradual	0.83	0.94	0.83	1.05	1.04	1.01
7	Boiler plate steel	1.00	8	60,000	13	31.60	23.10	27.00	1,460	1,208	1,358	Impact						
		0.50	8		19	29.00	23.20	25.70	1,370	1,047	1,230	Gradual	0.78	0.79	0.74	0.67	0.64	0.62
					4	36.90	31.30	34.40	2,035	1,690	1,855	Impact (2 blows)						
8	Soft steel castings	0.50	2	62,000	5	29.50	26.50	28.20	1,666	1,342	1,450	Gradual	0.84	0.85	0.85	0.67	0.64	0.62
9	Hard steel castings	0.50	2	82,000		35.00	31.00	33.00	2,467	2,080	2,315	Impact						
10	Locomotive tire steel	0.62	3	140,000	30	30.00	3.00	13.10	2,000	212	976	Gradual	0.81	1.00	0.91	0.35	0.23	0.33
			3	60,000	30	37.00	3.00	14.30	5,650	890	2,918	Impact						
11	Norway iron	0.305	72	63,000	1			18.70			649	Gradual			1.03			0.98
			108		3	19.40	16.70	18.10	727	550	656	Impact						
												Average	0.81	0.97	0.83	0.69	0.79	0.77

Except where noted impact tests were made with one blow at atmospheric temperature on test bars of same length as used in gradual tests. The elongation is that after rupture (measured from broken ends). The rupture-work is that up to rupture.

replaced by the term "total resilience." Strictly speaking, the term "resilience" refers to the elastic energy stored up in a body at any stage of deformation.

"Unit rupture-work" is the rupture-work per unit of volume. Thus if a bar of steel $\frac{1}{2}$ inch in diameter and 8 inches long is ruptured in tension as the result of a blow of a 512-pound hammer falling from 5 feet, thereby bringing the hammer to rest, the total rupture-work will be 2560 foot-pounds, and the unit rupture-work will be 1630 foot-pounds per cubic inch of metal.

MACHINES AND TESTS, TEMPORARY APPARATUS.—Two different machines, both vertical, have been used in these tests. For the tests on the specimens of steel wire 9 feet long (Nos. 1 to 4 in Table 2) a temporary wooden machine was constructed



FIGS. 1 and 4.—Diagrams of Temporary (Wooden) and Permanent (Iron) Machines for Testing Materials in Tensile Impact.

as shown in principle in Fig. 1,* and in construction in Fig. 2. This apparatus for producing longitudinal impact in tension was modeled after an apparatus used at Cornell University by Mr. Charles W. Comstock in impact tests of steel wire rope during 1898.† The principle therein employed, by which the hammer

* Acknowledgment is made to the Engineering News Publishing Company for most of the cuts used in this paper.

† Trans. Cornell Soc. C. E., Vol. 6, 1898.

is hung on the specimen and impact is effected by sudden arrestment, during the fall, of an upper moving head, also fixed to the specimen, has been used in France in certain foundries.

In Fig. 2 may be seen the arrangements for hanging the

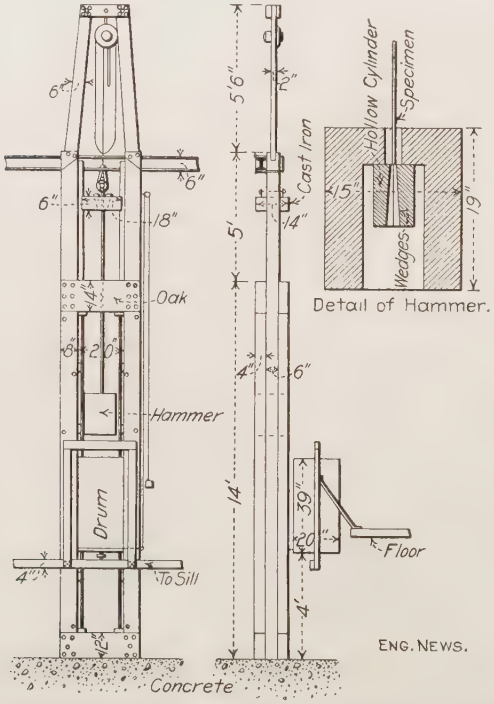


FIG. 2.—Temporary Tensile-Impact Testing-Machine; Sketch at Right Shows Method of Fastening Hammer to Lower End of Test Specimen.

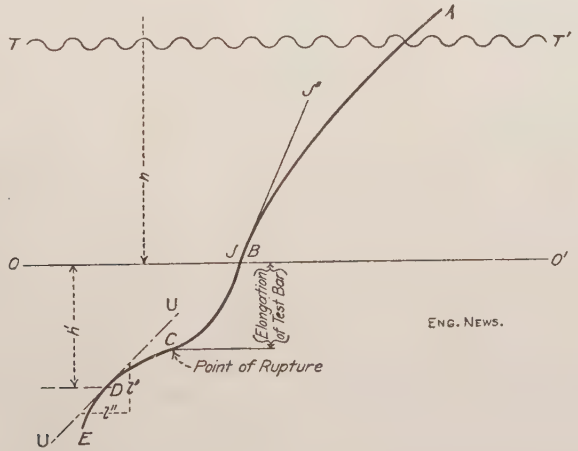
hammer on a head which is fixed to the lower end of the test specimen by wedges. A similar head is fixed to the upper end of the test specimen. The writer improved this form of apparatus by supplying a rotating drum (D, Fig. 1), upon the surface of which a pencil, attached to the hammer, records a curve during the impact. The vertical ordinates to this curve, called a time-displacement curve, are the movements of the hammer; and the horizontal abscissae are proportional to the speed of the surface of the drum. The latter speed is known from the record of a vibrating tuning fork, held against the drum. The velocity of

the hammer may be computed from the drum record at any stage of descent.

In operation, the system (Fig. 1), consisting of hammer, M, specimen B, and upper head C, is raised. Upon release, and subsequent descent, the upper head has impact upon a stop on bridge P, and the energy of the moving hammer thereby ruptures the test-specimen. The pencil attached to the hammer is automatically released before the impact occurs, and the above mentioned record is thereby written on the surface of the drum.

The energy remaining in the hammer after the rupture of the test bar is computed from a measurement of the velocity of the hammer at the time of rupture. This latter velocity is obtained from the slope of a tangent in the velocity-displacement curve.

Principle of Action.—As the discussion of the method of determining that part of the energy of the blow which is given up to the specimen will apply to the second machine described below, it is well to introduce the discussion here.



OO′ = Zero datum line.
AB = Free fall before rupture.
BC = Curve during Impact Elongation.
CE = Free fall after rupture.
UU = Tangent to curve of free fall.
h = Height of fall.
h′ = Height from datum to point D, where tangent is drawn.

FIG. 3.—Autographic Record and End-Tangent Method of Analysis.

Fig. 3 is a representation of the record on the drum, and is thus explained:

With the upper head resting on the stop and the hammer hanging on the specimen, the pencil attached to the hammer is allowed to rest against the drum. The latter is rotated, and a datum line O O′ is thereby traced. Any subsequent movement of the pencil below this line represents an elongation of the test specimen together with any yielding of the parts of the apparatus.

The system, consisting of hammer, specimen and upper head, is then hoisted and released. During the subsequent fall, the pencil attached to the hammer records on the revolving drum a parabola of free fall, A B. When the upper head has impact on the stop (P, Fig. 1) a retardation of the hammer is effected through the reaction of the test specimen. The curve B C is the record of the effect of the impact in retarding the hammer. The specimen is ruptured at the point C, and the record is then another parabola of free fall C E.

T T′ is the record of the stylus fixed to the vibrating tuning fork, which is held against the drum during the impact.

The use of this drum record in computing the desired quantities depends upon the following considerations. Neglecting, for the present, losses of energy due to friction and yielding of the parts of the apparatus, let us suppose that the hammer falls from the point of release, a height, $h + h'$, to some point D taken on the parabola of free fall subsequent to rupture. (The point C might have been selected, but the selection of the point D offers more favorable conditions for graphical work.) The entire quantity of work represented by the product of the weight of the hammer G into the distance $h + h'$ is accounted for:

(1) By the work expended upon the resistance of the test specimen during elongation;

(2) By the energy remaining in the hammer at D, or, in the form of an equation,

$G\ (h + h') =$ Work on test bar $+ \frac{1}{2} M V^2_d$.

$M =$ Mass of G.

$V_d =$ Velocity at D.

The quantity $\frac{1}{2} M V^2_d$ may be considered as replaced by the quantity Gh_d where h_d equal the velocity head at D.

$G\ (h + h') =$ Work on test bar $+ Gh_d$

Or, Work on test bar $= G\ (h + h' - h_d$

TABLE I.—COMPARISON OF RUPTURE-WORK AS OBTAINED FROM: 1, LOAD ELONGATION DIAGRAM, AND 2, END-TANGENT METHOD.

(Tensile Impact Tests of Annealed Steel Wire.)

Annealed Steel Wire.

Diameter, 0.265 in. Area of Section, .055 sq. in.

TEST A

Gage length, 108 ins.	Drop, 57 ins.	Wt. of hammer, 845 lbs
No. of piece.	Rupture-work by diagram. Ft.-lbs. per cu. in.	Rupture-work by end tangent. Ft.-lbs. per cu. in.
1	685	683
2	715	699
3	521	443
4	527	528
5	...	453
Average	612	561
Gage length, 108 ins.	Drop, 70 ins.	Wt. of hammer, 845 lbs.
6	...	596
7	655	626
8	615	608
9	610	626
10	645	673
Average	631	626

TEST B.

Gage length, 69 ins.	Drop, 38 ins.	Wt. of hammer, 845 lbs.
1	...	571
2	723	723
3	613	623
4	720	737
5	590	605
Average	665	633

This sum, $h + h' - h_d$, may be considered as the effective distance through which the hammer falls in rupturing the test bar.

Evidently it is necessary to measure the velocity V_d in order to obtain the desired rupture-work of the test bar.

This velocity is obtained by drawing a tangent U U at D and measuring the relation of the vertical to the horizontal projections l' and l'', *i. e.*, the relation of the velocity of the hammer to the velocity of the drum. The latter velocity is obtained from the tuning fork record. The duration of the impact will be the distance l'' expressed in seconds.

Thus to take an example from the test records:

Test No. 96.

Observations:

Tuning fork; 126 vibrations per second.

7 vibrations in 7.5 inches of drum.

$l' = 2.05$ inches; $l'' = 3$ inches; $h' = 1.6$ inches; $h = 7$ feet.

Calculations:

Velocity of drum = 11.25 feet per second.

Velocity of hammer at D = $11.25 \times 2.05 \div 3 = 7.78$ feet per second.

Velocity of head at D = 0.945 feet.

Rupture-work = 515 (7.133-0.945) = 3,186 foot-pounds.

The volume of the bar under test was 1.63 cubic inches; hence the unit rupture-work equals $3{,}186 \div 1.63 = 1{,}950$ foot-pounds per cubic inch.

This calculation neglects the friction of the guides, and other losses of energy due to the deformation of parts of the apparatus. As far as the friction of the guides during the greater part of the drop is concerned, this may be eliminated by drawing a tangent J J′ at B. In all the tests made with the first temporary apparatus the velocity head at B, computed from tangent J J′, was used instead of quantity h, thus eliminating the friction in the guides as far down as B. There were other losses of energy in this temporary machine, namely,

(*a*) At striking surfaces of upper head;

(*b*) Deflection of bridge;

(*c*) Slipping of wedges;

(*d*) Compression of heads of specimen;

(*e*) Pile action of the whole machine;

(*f*) General vibrations.

(*a*) The striking faces were metal, and after a complete series of tests had been completed no noticeable damage had occurred at these surfaces. Therefore, there must have been little lost work in any one test. The elastic compression is, of course, small.

(*b*) The total elongation of the specimen was generally 12 to 14 inches, and the greatest observed downward movement of the bridge was nearly $\frac{1}{8}$ inch. This would cause an error of between 1 and 2 per cent in rupture-work.

(*c*) and (*d*) The wedges were driven tight with a sledge-hammer before impact occurred, thus taking up in advance any compression of the heads of the specimen and preventing slipping of the wedges.

(*e*) and (*f*) These cannot well be measured. The writer assumes that the energy represented by vibrations is small.

In the case of the long rods, in which the elongation was as much as 14 inches, there was an opportunity to divide the curve B C into a number of parts. At each division point a tangent was drawn. The loss of velocity at the successive stages was computed from the observed change of slope of these tangents. Then the force necessary to account for the loss of velocity between the division points was computed by the principles of dynamics.

Let P = Retarding force in pounds.

p = Acceleration of hammer (negative).

G = Weight of hammer.

T = Total tensional force in specimen.

$$G - T = \frac{Gp}{g}, \text{ or } T = G - \frac{Gp}{g}$$

In this manner the tension in the specimen was computed at various stages of elongation, and thus a "load-elongation diagram" was constructed for the impact tests in tension. Some of these diagrams are shown in Fig. 15. The evaluation of these diagrams should yield the same amount of rupture-work as that obtained by the process outlined above, namely, the process in which the velocity head after rupture was computed, called the "End Tangent Method." The accompanying Table I is a comparison of the unit rupture-work obtained by the two methods.

The experiments performed on this temporary apparatus include the following:

1. A series of comparative tests of long steel and iron rods under slow and impact loading—1898.

2. A series of tests of steel wire of different lengths, and the determination of the effect of temperature on tests of wrought iron—1899.

In these experiments the weight of the hammer varied from 845 to 1230 pounds, and the greatest height of fall was 6 feet.

In Table II the material under the reference numbers 1, 2, 3, 4 and 11 was tested on this temporary apparatus.

Permanent Machine.—The experiments performed on the

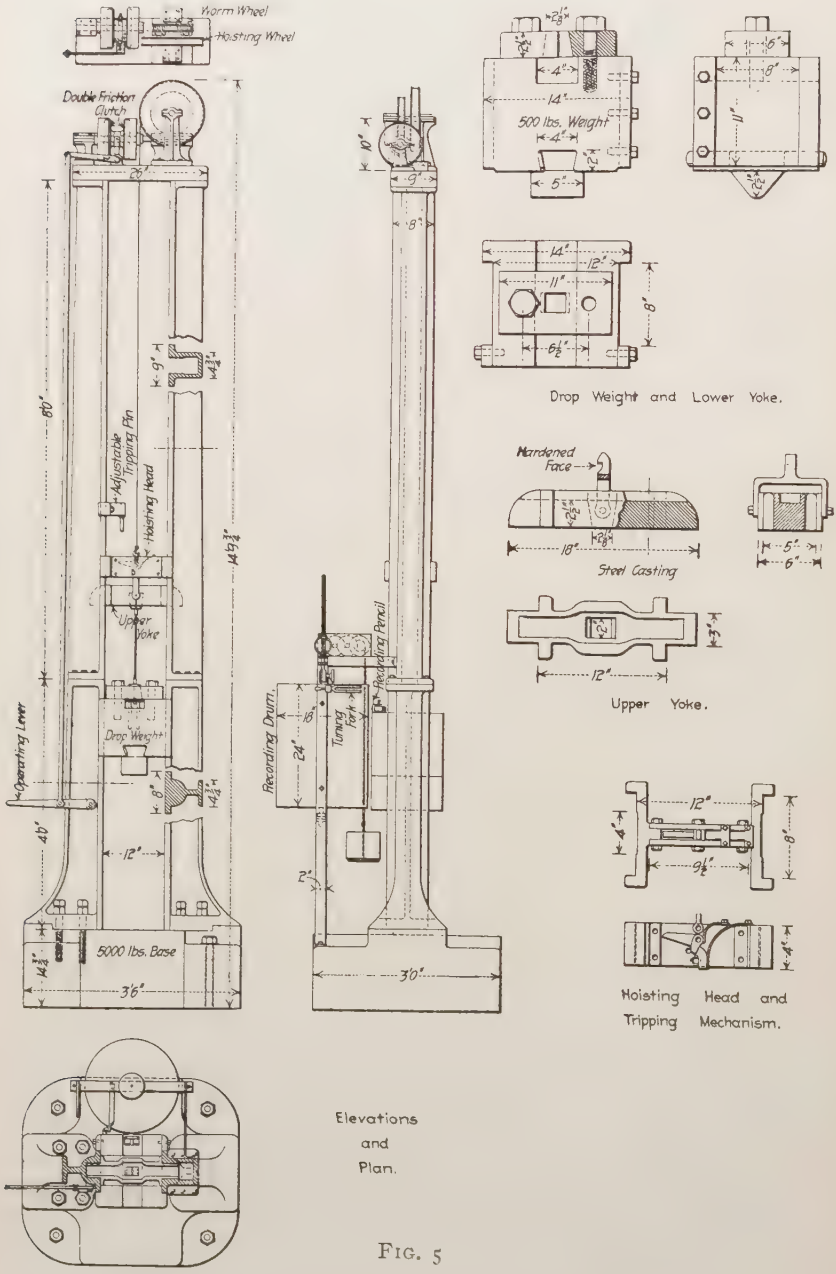

Worm Wheel
Hoisting Wheel
Double Friction Clutch
Adjustable Tripping Pin
Hoisting Head
Upper Yoke
Drop Weight
Operating Lever
5000 lbs. Base
Recording Drum
Tuning Fork
Recording Pencil
500 lbs. Weight
Drop Weight and Lower Yoke.
Hardened Face
Steel Casting
Upper Yoke.
Hoisting Head and Tripping Mechanism.
Elevations and Plan.

FIG. 5

temporary apparatus were successful enough to encourage the construction of a more permanent machine in metal (Fig. 5). This machine has been described elsewhere in detail,* and will in this place only be described in general. The permanent machine is similar to the temporary apparatus in principle (see a comparison in Figs. 1 and 4). Better adjustment for short specimens is brought about by dispensing with the bridge (P in Fig. 1) and constructing the upper moving head so as to span the distance between uprights as shown. This upper head or yoke is stopped directly by the lower sections of the columns. The details of attachment of the weight, recording apparatus, hoisting mechanism, etc., were of excellent workmanship. The parts were designed to rupture, in one blow, a test specimen of soft steel $\frac{1}{2}$ inch in diameter and 8 inches between heads. Ordinarily the blow delivered is about 3,500 foot-pounds. The machine rests on a brick foundation 5 feet by 5 feet by 6 feet deep, laid in natural cement on undisturbed gravel foundation. The upper four courses are of paving-brick in Portland cement. A $\frac{3}{4}$-inch bearing bed of 1 to 1 Portland cement mortar is disposed between the bed-plate and the pier. The machine is also available for compression tests.

An estimate was made of the energy lost in the various parts of the apparatus, thus: The parts of the apparatus that could be operated upon were loaded in a static testing machine and the consequent deformations observed. For example, the upper and lower yokes were placed in a statical testing machine with test bar and wedges attached and the deformation obtained under various central loads. From these observations the amount of energy absorbed by the upper or lower head at any given deflection could be computed. It only remained to observe the actual deflection which took place in these heads under the impact test to obtain a knowledge of the loss of energy corresponding to deflections of these heads in service. In this manner the main losses of energy could be estimated quite closely. The losses of energy at the striking surfaces cannot well be measured in any one test, but we may obtain some estimate of their amount by observing the cumulative effect at these striking surfaces after a long series of tests. The friction between the hammer and the guides can

* Engineering News, January 3, 1901, or Nouveaux Appareils d'Essa —Congress International des Methodes d Essai, Paris, 1900, Vol. 1, p. 507.

easily be measured either by statical methods or by finding the loss of velocity at different stages of the descent. The value of the acceleration of gravity measured by dropping the hammer and determining its velocity ran from 31.7 to 32.0 feet per second.

The author estimates the losses in this machine as follows, when tension bars of soft steel are tested:

At the upper and lower head, due to the deflection of the yokes 7 to 11 foot-pounds. Friction of guides 8 foot-pounds. At wedges, 0. For a total energy of blow 2,000 foot-pounds, the energy not chargeable to specimen is less than 1 per cent.

It may be said, with reference to loss of work due to the slipping of the wedges or compression of the heads of the specimen, that, before testing a specimen, the top wedges were driven tight with a sledge-hammer and the bottom wedges pinched with a bar. Careful observations showed no slipping of the wedges due to the impact. What are the losses of energy due to permanent deformation at the striking surfaces of the upper head, and due to the vibration of the entire apparatus, etc., the writer cannot say. But since no permanent deformation seems to have resulted after some hundreds of tests, one must reason that the first of these is small.

In conclusion, the author believes that the uncertainties of the measurement of the amount of energy taken up by the specimen are small compared with the ordinary differences of quality as displayed under static tests of adjoining specimens in any rod or plate of even normal quality. The results obtained on this machine may, in the author's opinion, be relied upon for all practical purposes. The author does not share the feeling of those who would disregard the use of impact tests because of the small losses of energy that cannot be accounted for. This machine also serves as a laboratory apparatus for instructional purposes. Not only is the student impressed with the phenomena of rupture, but the observations and calculations bring home to him the mechanical relations of work, energy, etc.

In the experiments with this permanent machine, the weight of the hammer varied from 515 to 870 pounds, and the greatest height of fall was 6 feet. The work performed with the aid of this machine includes the following:

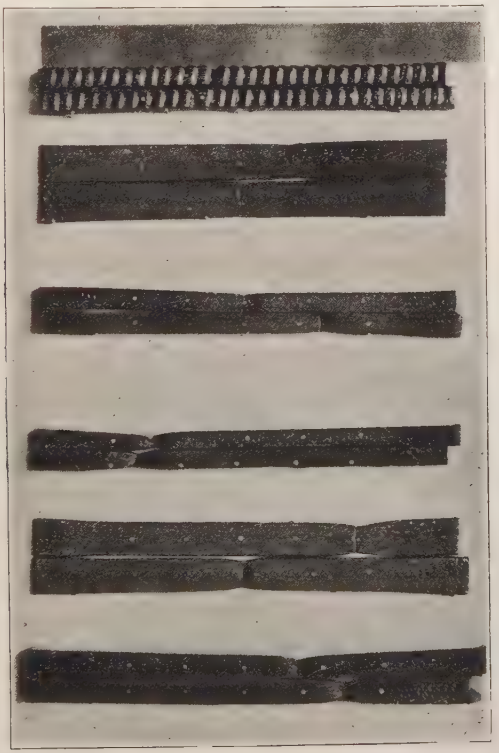
Tests of nickel steel and soft carbon steel in tension under

gradual and impact loading. Effect of speed of application of a given amount of energy. Effect of temperature on the resilience of soft and nickel steel—1900.

Tests of steel castings in tension and flexure. Tests of cast iron in flexure. Tests of concrete in flexure and compression—1901.

RESULTS.

Comparison of Impact and Static Tests.—One of the first matters of interest is the relative behavior of material under impact and slow loading. It is also important to know how far the



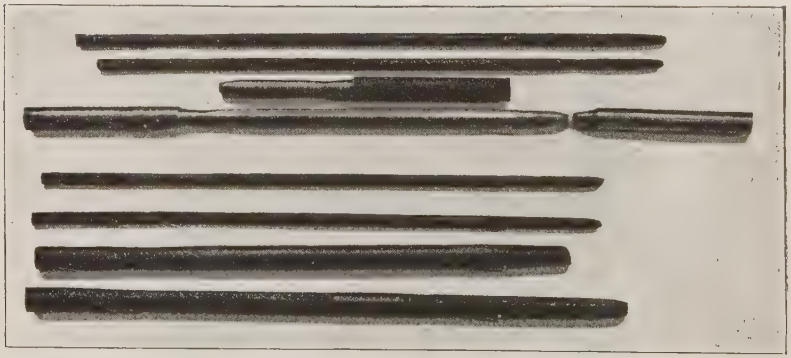
The upper bar of each pair was broken by Gradual Loading.
The lower bar of each pair was broken by Impact Loading.

FIG. 6.—Test-Bars Broken Under Gradual and Impact Loading in Tension.

ordinary static test will yield information of the relative shock-resisting capacity of various materials. Table II is a tabulation of results of such comparative tests.

It appears from the results given that in the case of normal soft material, in bars of circular cross section, of lengths from 9 feet to 8 inches, tested at ordinary temperatures, there is little difference in the total elongation and unit rupture-work whether the bar is ruptured in ten minutes or in from one to two one-hundredths of a second. The only marked point of difference in the static and impact tension test of soft materials of greater lengths is that under impact any lack of homogeneity of material is brought more into evidence. There is a tendency in non-homogeneous materials under impact to localization of the elongation of a test bar at various points in the gage length, so that the latter consists of nodes of ductility. After rupture the bar may have a number of incipient necks. In many cases two distinct necks are formed, as is shown in Fig. 7. The effect may be noticed in static tension tests, but not, in the author's experience, to the same degree as in impact tests. There is also a tendency, under impact, to localization of elongation near the wedges.

A marked difference between the results of gradual and impact



The four upper specimens show the phenomenon of multiple necking in ordinary impact tests.

The four lower specimens were subjected to freezing along the center portion before and during fracture.

FIG. 7.—Impact-Test Bars Showing Double Necking, and Effect of Freezing Center Portion.

tests may be noticed in case of short bars of steel castings and of tire-steel and coupons from boiler plate. There is a greater elongation and unit rupture-work under impact in the case of soft steel castings. But in the case of the harder steel, like tire-steel, the increase in unit rupture-work is disproportionate to the increase in elongation. This is partly due to the fact that there is considerable metal between the gage marks and the wedges in these steel castings, whereas the unit rupture-work is computed on the basis of the volume within gage marks. It may be said that a larger amount of energy disappears in the parts of the machine in case of test pieces of harder metal. The latter increase is probably small.

The tests cover a range from soft steel castings to hard tire-steel, and a range of gage length from 2 inches to 9 feet. All comparisons, however, made between static and impact tests of any one material are based on bars of the same gage length for the two kinds of tests, and represent tests in which the bars were broken in one blow except as where noted.

Table II shows the quality of the material and the average, as well as the maximum and minimum values observed. The comparison of the two kinds of tests given by Table II is graphically

TABLE III.—SOFT STEEL CASTINGS, 2-INCH GAGE LENGTH.

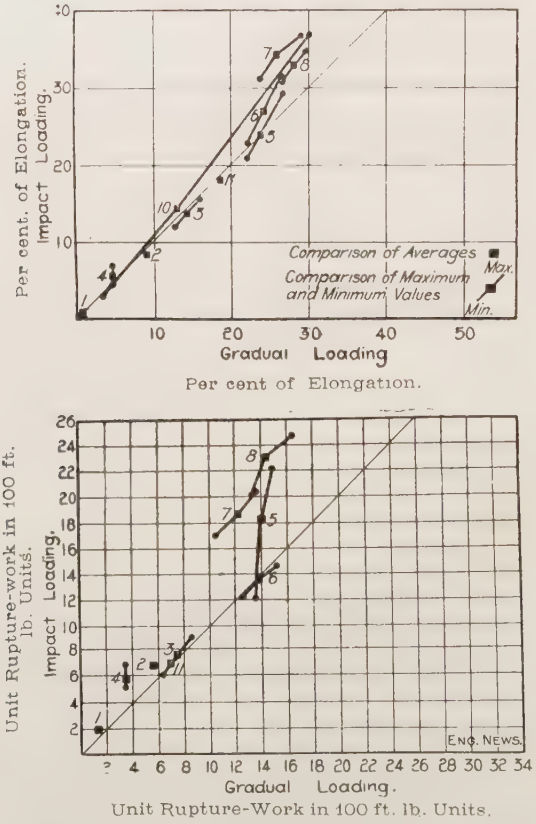
Kind of test.	Number tested.	Elongation.			Rupture-work.			Contraction.		
		Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.
Gradual	5	28.2	29.5	26.5	1,450	1,666	1,342	46.0	54	40
Impact	5	33.3	35.0	31.0	2,315	2,440	2,080	44.2	40	40

TABLE V.—LOCOMOTIVE TIRE STEEL.

Number tested.	Elongation, Per cent.			Rupture-work, ft.-lbs per cu. in.			Kind of test.	Carbon.
	Max.	Min.	Aver.	Max.	Min.	Aver.		
6.....	10.0	3.0	7.16	.....	.....	.....	Gradual	Above 0.70.
	13.0	3.0	5.90	3,920	904	2,403	Impact	
4.....	28.0	13.0	19.20	.....	.....	.....	Gradual	Above 0.70.
	23.0	10.0	16.50	4,170	2,200	3,272	Impact	annealed.
4.....	21.0	10.0	16.20	.....	.....	.....	Gradual	0.60—0.69
	22.5	17.5	20.60	5,650	1,500	4,000	Impact	not annealed

NOTE.—The Gradual results in Table V are taken from mill reports.

shown in Fig. 8, in which both axes are equal scales of the same kinds of quantity; if there were no effect of speed the plotted points would lie on the 45° line drawn on Fig. 8. Comparison of averages is plotted as a point, and also the comparison of the



The upper diagram is for Elongation. The lower diagram is for Unit Rupture-Work.

FIG. 8.—Comparative Elongation and Unit Rupture-Work, Gradual and Impact Loading in Tension.

maximum values and the comparison of the minimum values. The elongation is always that obtained by measurements on the broken ends of the test bars. The rupture-work for the gradual tests was worked up from observations taken on specimens. In the case of

long rods and very short rods this was done by direct measurement, and in the case of specimens of 8-inch gage length the rupture-work was obtained by the use of the Henning Pocket Recorder. An exception must be made in the case of tire-steel.

It has been said in a previous paragraph that the elongation is always that obtained by measurements on the segments of the broken test bars. The rupture-work is, of course, the total rupture-work up to the point of rupture. In the case of these long rods there was a noticeable difference between the elongation of the rods as shown on the drum record and the elongation as determined by laying the broken ends of the specimen together

TABLE VI.—VARIATION OF ELONGATION AND RUPTURE-WORK WITH GAGE-LENGTH.

Tensile Impact Tests.

	Machine Steel.		Soft Steel.		Annealed steel wire.	
Gage length.	Elongation.	Rupture-work.	Elongation.	Rupture-work.	Elongation.	Rupture-work.
3-in.	100	100				
4.5-in.	98	89				
5-in.	83	82				
5.5-in.	77	66				
6-in.	92					
6.5-in.	104	93				
7-in.	89	79				
8-in.	84	78				
11-in.			71	60		
12-in.					23	50
14.5-in.	73	60				
18-in.			64	56		
19-in.			70	60		
23-in.			57	52		
25-in.			61	56		
25.5-in					18.5	36
26-in.					18.5	32
108-in.					15	25

Results are based on the value of 3-inch gage length as 100.

and measuring the increase of length between the gage marks. This difference is too great to be accounted for by the supposition that the increased elongation as shown on the drum is due to the yielding of the parts of the apparatus. The difference is no doubt due to the elastic stretch at rupture and subsequent recoil upon the breaking of the bar. For instance, in No. 2 annealed wire

(see No. 4, Table II) the total elongation after rupture on broken test bar was, on the average, 5.46 inches, and the elongation shown on the drum just before rupture was 7.29 inches. This phenomenon was also noticed in the slow tension tests on the same material. Twenty-eight impact tests of annealed wire show an average difference between the elongation before and after rupture of 0.18 inch per foot of length of bar. Six tension tests under gradual loading gave an average between these two measurements of elongation of .055 inch per foot. The difference between the elongation before and after rupture is thus about $3\frac{1}{2}$ times as great in the case of impact tests as in the case under gradual loading. In the case of harder steel wire this difference between the two elongations was 0.12 inch per foot, and was the same in gradual and impact tests.

In the case of the tire-steel the rupture-work was computed from a knowledge of the results of static tests by substitution in a well-known formula which gives the approximate rupture-work. This formula is as follows:

$$\text{Rupture-work} = \frac{e}{300}(T' + 2T'').$$

Where e is the per cent of elongation at rupture, T′ is the elastic limit, and T″ is the ultimate strength.

The rupture-work of steel castings under gradual loading was also computed by the application of this formula to the results of gradual test made some time before in the laboratory by the writer, on bars of the same heat number. In order to check the application of this formula to steel castings of 2-inch gage length and $\frac{1}{2}$ inch in diameter, a special series of tests was made on this material. The actual measurements during elongation were taken on 2-inch gage length and the stress-strain diagram therefrom resulting was evaluated in order to obtain the rupture-work. The actual measurement of rupture-work was compared with the results from the application of the formula given above. This showed that the formula applies with a small limit of error (see Table XII).

Information is given in Tables III, IV and V more in detail concerning the properties of steel castings and locomotive tire-steel under impact. Table III shows a special comparison of five soft

annealed steel castings of a fine silky fiber under impact and gradual loading, when broken with one blow of a 580-pound hammer, falling through an effective distance of about 1.45 feet. Table IV gives the average properties of steel castings of different character as shown by the appearance of fracture. Table V gives detail information of the same kind with respect to locomotive tire-steel.

The material in Table II is described as follows: The steel wire specimens were cut from one length of wire which was either annealed or not annealed as indicated. This wire was supplied by the Trenton Iron Company. The nickel-steel was sent from the Carnegie Steel Company and was from one heat and rolling. Analysis as follows:

	Per cent.
Carbon	0.21
Phos.	0.013
Mang.	0.60
Sulph.	0.026
Nickel	3.15

The soft steel was purchased on the market in the form of rods of 16 feet length. The boiler plate specimens were coupons from plates rolled for a single order to be used in locomotive boilers. Steel castings were machined coupons which were cast on the rims of locomotive driving-wheel centers, and were generally annealed. They were supplied by the Peru Steel Casting Company, Peru, Ind., from heats selected by the writer on the basis of static tests. The locomotive tire-steel was sent from the mill of the Standard Steel Works. The static tests on the tire-steel were derived from the mill reports. The comparison quoted includes both annealed and unannealed bars. This comparison of tests on locomotive tire-steel is somewhat unsatisfactory in detail for the reason that some of the bars are annealed and some not annealed. The average, however, is significant.

THE EFFECT OF VARIOUS FACTORS ON THE RESULTS OF IMPACT TESTS.

Gage Length.—In static tests both elongation and rupture-work increase with diminished gage length. The effect of change of gage length upon the results of impact tests was investigated in

order that results might be reduced to a common basis when bars of varying gage length have been tested. Three different kinds of material were used. Series A consisted of a number of bars machined, varying in gage length from $2\frac{1}{2}$ inches to $14\frac{1}{2}$ inches. The specimens were all broken with one blow of a hammer weighing 515 pounds. These specimens were machined from rods to a section $\frac{5}{8}$ inch in diameter.

Series B consisted of rough soft steel bars, 5-16 inch diameter, varying in gage length from 11 inches to 25 inches. Series C consisted of specimens of annealed steel wire varying in length from 12 to 108 inches. The results are shown in Table VI.

The contraction of area seemed not noticeably affected by the gage length, but it is very evident that the unit rupture-work and per cent of elongation increase as the gage length decreases. This

TABLE IV.—STEEL CASTINGS OF VARIOUS KINDS.

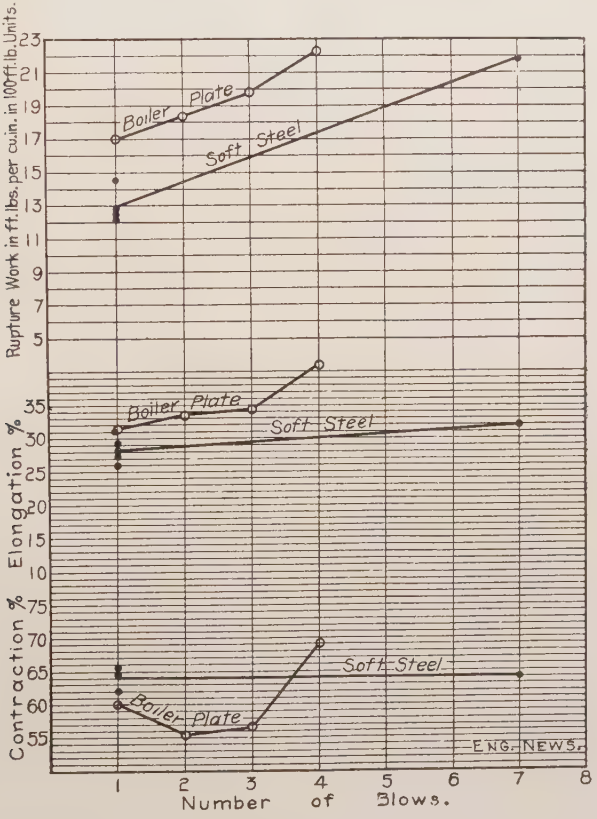
Character of fracture.	Kind of test.	Elongation.	Rupture-work.	Contraction.
Silky	Gradual	26.0	1,338	39.9
	Impact	30.0	2,160	40.0
Flaky	Gradual	21.6	981	31.5
	Impact	19.0	900	18.8
Fine bright	Gradual	17.4	744	20.3
	Impact	22.6	2,811	23.2

effect is due (1) mainly to the work of deforming the bar at the neck, which work bears a greater proportion to the total work in the case of short gage length, and so increases the rupture-work per cubic inch; and (2) partly due to the fact that the work done in stretching the metal between the gage marks and the wedges is a greater proportion of the total. The increase in per cent of elongation and unit rupture-work may not be expected to increase indefinitely, because when the reduced section becomes a "nick" both of these diminish. There must be then a particular gage length for maximum value of these quantities.

Number of Blows.—It was the intention in all the writer's tests to produce rupture in one blow. Sometimes, however, unknown material came into the laboratory, the impact resistance of which was not known in advance, and the bar had to be broken sometimes by two, sometimes by three, blows. It seemed necessary, therefore, to determine the relative properties exhibited by

material when tested with one or two or three blows, as the case might be, applied a few minutes apart, in order that the result might be reduced to the standard of one blow.

To determine these relations three series of bars were used. Series A consisted of five specimens of boiler plate (No. 7 in Table



F.G. 9.—Effect of Number of Blows on Elongation, Contraction and Rupture-Work Under Tensile Impact.

II). Series B consisted of specimens of rough bars of soft steel. Four specimens were broken with one blow, and one specimen broken with seven blows. Series C consisted of steel castings 2 inches in gage length and $\frac{1}{2}$ inch in diameter, broken with either one blow or a number of 6-inch blows. The results are as shown

in Table VII, and Fig. 9. The ductility and rupture-work increase with the number of blows in spite of the hardening effect of the first and succeeding blows. In a test of a steel rod under twelve blows from 1 foot height, the hardening was evident in its effect on the recoil or rebound of the hammer. The recoil of

TABLE VII.—SHOWING COMPARATIVE EFFECT OF ONE BLOW AND A NUMBER OF BLOWS ON ELONGATION AND RUPTURE-WORK

Tensile Impact Tests.

	Boiler Plate.		Soft Steel.		Soft Steel Castings.		Hard steel castings.	
No. of blows.	Elongation.	Rupture-work.	Elongation.	Rupture-work.	Elongation.	Rupture-work.	Elongation.	Rupture-work.
1	100	100	100	100	100	100	100	100
2	106	.....	.....	.....	.....	.....	.....	.....
3	110	.....	.....	.....	.....	.....	.....	.....
4	132	.....	.....	.....	.....	.....	169	450
5	.....	.....	.....	.....	102	130	.....	.....
6	.....	.....	.....	.....	.....	.....	.....	.....
7	.....	.....	115	.....	.....	.....	.....	.....
8	.....	.....	.....	.....	.....	.....	.....	.....

Values quoted are on basis of 100 for value at one blow.

the hammer from the first blow was 0.3 inch; from the sixth, 0.5 inch; from the tenth, 0.8 inch. The rupture-work quoted in the tables does not include the minor blows due to recoil following the parent blow.

TABLE VIII.—EFFECT OF SPEED OF DELIVERY OF ENERGY.

Series A—Annealed Steel Wire 0.26 Inch Diameter.

No	Length.	Number tested.	Weight of hammer, lbs.	Height of drop, ins.	Rupture-work,			Elongation.		
					Max.	Min.	Aver.	Max.	Min.	Aver.
1	108	5	845	57	683	443	609	6.95	4.30	5.06
2	108	5	845	70	673	596	626	6.90	4.60	5.71
3	108	5	1,230	36	680	497	587	5.40	4.00	4.76

Series B—Soft Steel, ½ Inch Diameter x 8 Inches Long.

5	8	5	515	60.5	1,471	1,237	1,365	30.00	25.00	26.2
6	8	8	810	36.5	1,502	1,215	1,317	24.00	32.00	27.3
7	8	8	Gradual test.		.....	.....	1,370	.....	.....	24.0

Velocity of Delivery of a Given Amount of Energy.—It seemed necessary to determine if, within the ordinary limits of impact tests on the machine, the speed of delivery of a given amount of

energy had an important effect on the results. That is to say, are the results the same whether the energy is delivered through the medium of a heavy weight falling through a small distance or

TABLE IX.—VARIATION OF ELONGATION AND RUPTURE-WORK WITH TEMPERATURE.

Tensile Impact Tests.

Temp. Deg. F.	Soft steel.		Nickel steel.		Norway iron.	
	Elongation.	Rupture-work.	Elongation.	Rupture-work.	Elongation.	Rupture-work.
—100	33	41	65	81	.....	.....
0	73	74	79	96	.....	.....
32	100	102	.....	.....	26	48
40	.....	.....	113	102	.....	.....
70	100	100	100	100	.....	.....
80	.....	.....	.....	.....	100	100
212	104	100	100	82	165	138
400	94	80	87	61	.....	.....

Values quoted are on basis of 100 for value at 70° F.

whether through the medium of a lighter weight falling through a greater distance? Of course in extreme limits there would be noticeable differences of effect. The writer's experiments directed to this question are shown in Table VIII. The conclusion is that the results are not sensitive to the ordinary changes of velocity of application to be expected in any one impact machine.

Temperature of Test Bar.—To determine the law controlling the variation of resistance in change of temperature under impact, the writer has used specimens of soft steel and nickel steel (Nos. 5 and 6 in Table II). The specimens were broken with one blow each.

The method of producing the desired temperature in the test bar is as follows: To obtain a temperature of 32° F. the test bar, together with the wedges, was allowed to lie in cracked ice for 30 minutes before test. The bar was then surrounded with an asbestos-wrapped tin cylinder 2 inches in diameter and 9 inches long, which held cracked ice, and then rapidly fixed in the machine. With the tin cylinder still on the bar, the system was hoisted, released, and impact then occurred. The time from the removal of the bar and the wedges from the cracked ice until the time of

impact is estimated at about 8 minutes. Of course during this period the guides and yokes of the apparatus were delivering heat to the wedges and test bar, and thereby producing a gradient of temperature between the center of the bar and the upper and lower ends. The effect of this gradient is to tend to bring about

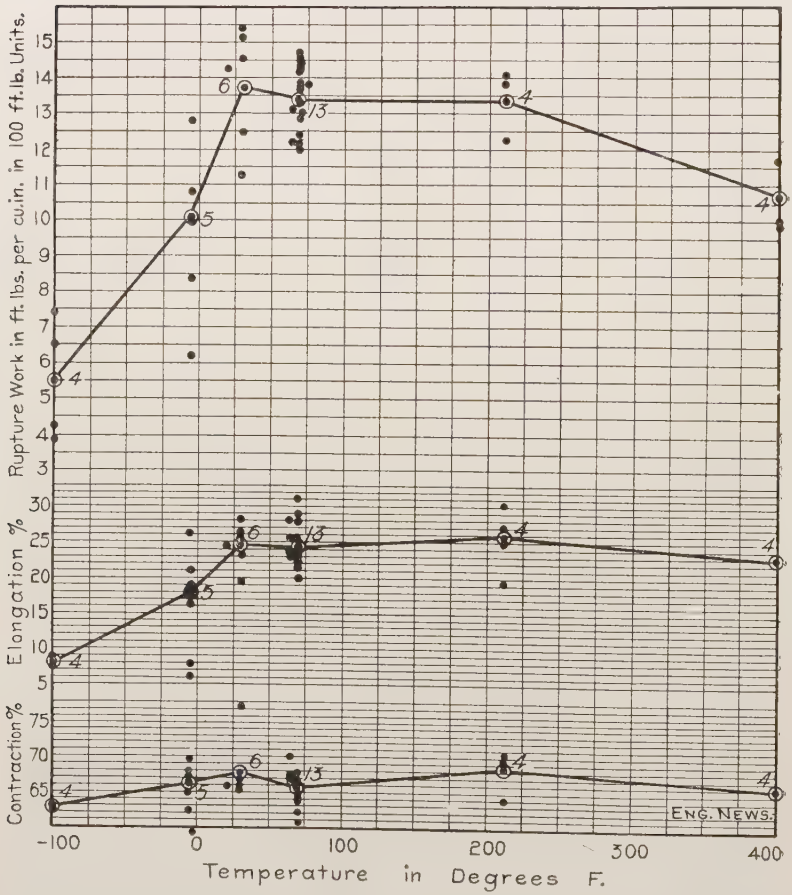


FIG. 10.—Soft Steel, ½ inch Diameter by 8 inches Gage Length.

rupture at the ends of the specimen rather than at the center. The temperature of 0° F. was effected, in the same manner as above described, by a mixture of salt and ice. The temperature

of −100° F. (estimated) was secured by a freezing mixture of carbonic-acid snow and ether, kept in the form of a slush. In all cases the bars were packed in the mixture before test and the cylinder containing the freezing mixture was placed around the bar during the entire period of the test. The temperature of the

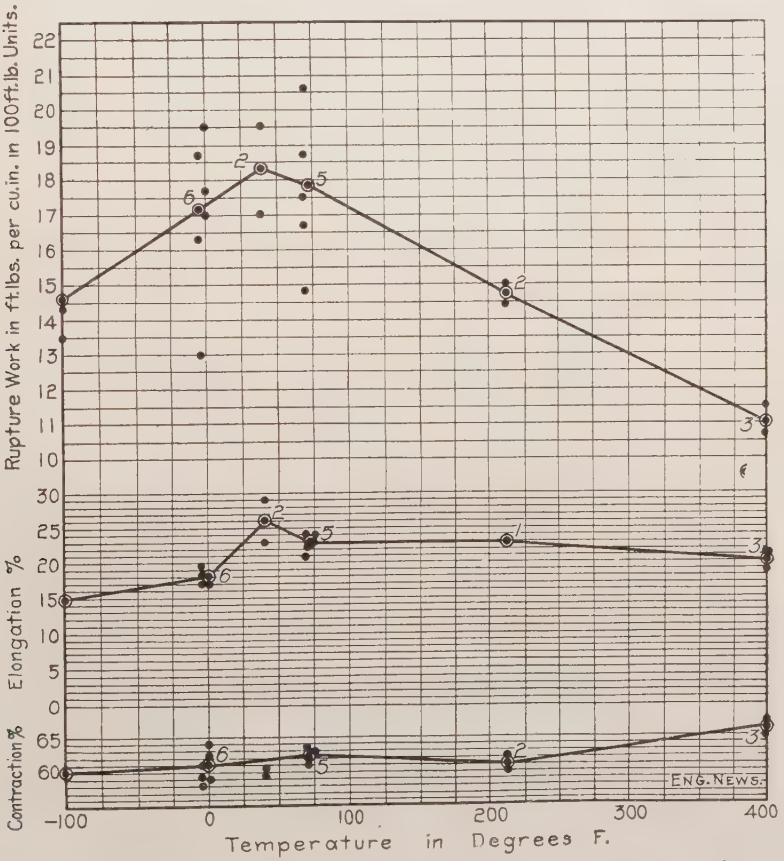


FIG. 11.—Nickel Steel, ½-inch Diameter by 8 inches Gage Length.

test bar is assumed to be that of the mixture. The temperatures of 212° F. and 400° F. were secured by filling the tin cylinder with a fluid, heating the fluid by a gas flame while the specimen was in the machine ready to be dropped. Boiling water was used for 212° F., and boiling linseed oil for 400° F. All the temperatures

were measured (except that of the slush of carbonic-acid snow and ether) just before the drop occurred while the bar was in the machine surrounded by the freezing mixture.

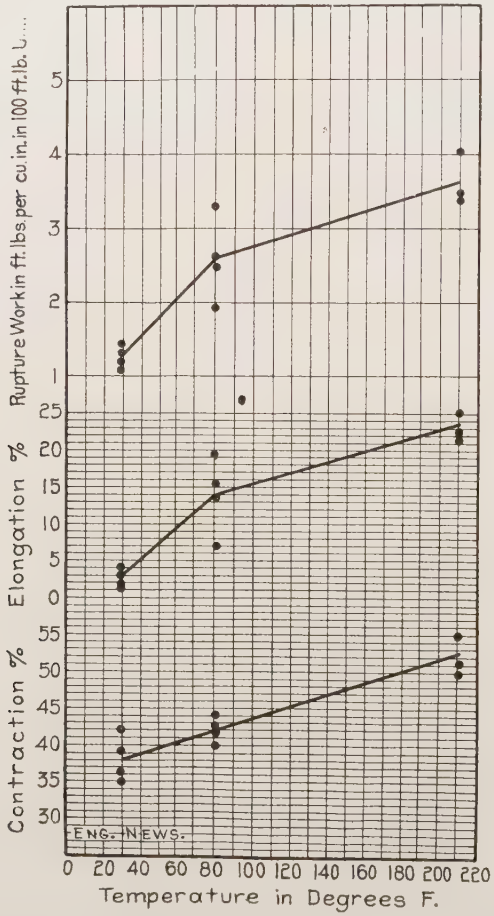


FIG. 12.—Norway Iron, $\frac{1}{4}$ inch Diameter by 60 inches long.

FIGS. 10, 11 and 12.—Effect of Temperature on Elongation, Contraction and Rupture-Work for Various Kinds of Steel, Under Tensile Impact.

The results of this investigation are shown in Table IX and Figs. 10 to 13.

It appears from these results that in the case of ordinary soft steel there is a diminution of elongation and unit rupture-work as

the temperature goes below 32° F. or above 212° F. In the case of nickel steel this diminution is apparent when the temperature goes below 32° or above 70°. The contraction seems not to be much affected by change of temperature. Even in case of the

TABLE X.—EFFECT OF TEMPERATURE ON ELONGATION AT FRACTURED INCH.

Tensile Impact Tests.

Temperature.	Inches elongation of fractured Inch.			
	Nickel steel.	No. of tests.	Soft steel.	No. of tests.
—100	0.40	3	0.46	1
0	0.44	6	0.48	3
80	0.49	8	0.49	8
212	0.53	1	0.52	2
400	0.54	2	0.45	1

bars cooled to −100° F. the fracture was so hot that the broken end of the bar felt uncomfortably hot to the touch.

The diagrams, Figs. 10 to 12, show the averages of all specimens tested. These individual specimens were taken from a number of long rods about 10 feet in length. In order to obtain the comparison of results on test bars taken from the same long rod, each test bar was marked with a number indicating the long rod from which it came; and the determination of the effect of temperature was made for each individual long rod. These individual comparisons more clearly show the same law that was obtained from the comparison of the averages of all test bars. In order to obtain a comparison in which the variation in quality of the long rods should be eliminated, Fig. 13 has been prepared. This figure shows the variation of mechanical properties with temperature. Here the results of all the tests at normal temperatures on various rods entering into the investigation are given a value of 100, and the corresponding rupture-work, elongation, etc., of the various test bars originating from the various rods are given values which show the relation of the results at the respective temperatures to the results at 70° F. That is to say, in long bar No. 1 the rupture-work at 70° F. was 1620, and the rupture-work of test bar No. 3 from long rod No. 1 at 0° was 1240.

A study of the distribution of the elongation in the ruptured

bars shows that the bars which were heated above atmospheric temperature have a tendency to break near the center, whereas

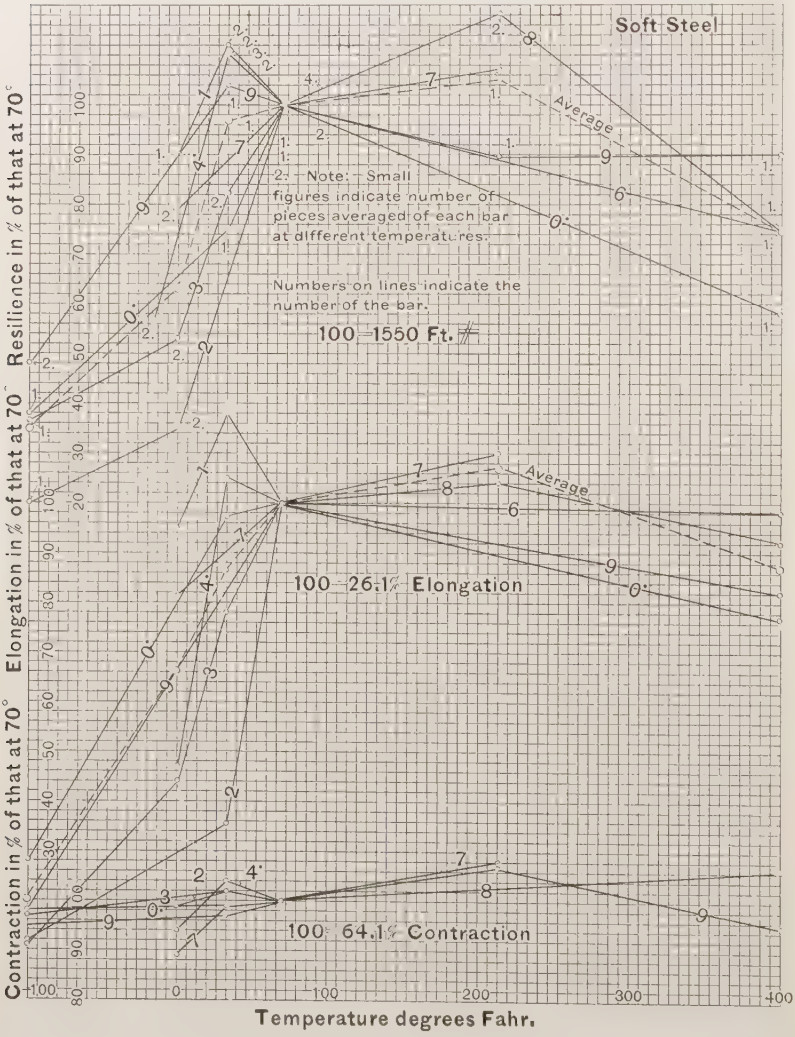

Soft Steel
Average
Note: Small figures indicate number of pieces averaged of each bar at different temperatures.
Numbers on lines indicate the number of the bar.
100—1550 Ft. #
100—26.1% Elongation
100—64.1% Contraction
Contraction in % of that at 70° Elongation in % of that at 70° Resilience in % of that at 70°
Temperature degrees Fahr.
-100
0
100
200
300
400

FIG. 13.

bars broken at low temperature break near the ends. At —100° the elongation of the bars of soft steel was not more than 1 per cent

at any inch which was at least 2 inches from the point of fracture. In many cases the part of the bar near the center was not stretched to a measurable degree. The nickel steel showed a more uniform elongation. This, in the writer's view, is due to the fact that under impact a bar tends to break at the warmer portions. To investigate this matter more thoroughly a few bars were purposely

TABLE XI.—EFFECT OF SHAPE AND SURFACE OF BOILER-PLATE ON ELONGATION AND RUPTURE-WORK.

Original Bar: Sides as in Original Plate, Milled Edges, 8-Inch Gage Length, 1 x 0.5 inch Cross-Section.

Modification of Specimen.	No. tested.	Elongation, Per cent.			Rupture-work in ft.-lbs. per cu. in.			No. of bl'ws.	Kind of test.
		Max.	Min.	Aver.	Max.	Min.	Aver.		
Original	19	29.0	23.7	25.7	1,370	1,047	1,230	.....	Gradual.
	4	36.9	31.3	34.4	2,035	1,690	1,855	2	Impact.
No fillets	1	.....	.....	27.0	.....	.....	1,260	.....	Gradual.
	2	28.0	27.0	27.5	2,791	2,391	2,591	2	Impact.
Nicked cross-section	1	.....	.....	3.5	.....	.....	180	.....	Gradual.
	2	0.12	0.11	0.11	385	374	379	1	Impact.
Polished all four faces	0	.....	.....	.....	.....	.....	.....	.....	Gradual.
	2	29.0	29.7	29.4	2,312	2,169	2,240	2	Impact.
Rasped, four faces	0	.....	.....	.....	.....	.....	.....	.....	Gradual.
	3	27.0	16.0	21.6	2,226	1,106	1,682	1–3	Impact.
Edges rounded to semi circle	1	.....	.....	26.5	.....	.....	1,116	.....	Gradual.
	2	34.0	27.0	30.5	2,052	2,019	2,035	2	Impact.
Turned and polished, dia.	0	.....	.....	.....	.....	.....	.....	.....	Gradual.
0.56 in. Area = .245 sq. in.	2	20.0	18.7	19.3	1,021	766	893	1	Impact.
Milled and polished, sec. 0.35	0	.....	.....	.....	.....	.....	.....	.....	Gradual.
x 0.70. Area = .245 sq. in	3	25.0	23.5	24.1	1,571	1,491	1,632	1	Impact.
Milled to square cross-section	0	.....	.....	.....	.....	.....	.....	.....	Gradual.
0.63 in. on side	2	31.0	27.8	29.4	.....	.....	1,990	2	Impact.

given a gradient of temperature. Thus the center of the bar was surrounded with the freezing mixture and the ends of the bar were heated by a gas flame; the frozen portion of the bar retained its original diameter and was not stretched by the blow, whereas the warm ends were drawn down to necks. Two bars were frozen at the upper ends and the lower ends were exposed; these broke at the lower ends. The frozen portions had been able to transfer the strain energy quickly throughout their length to the warmer portions where this energy was absorbed in deforming the material.* Fig. 7 shows some of the test bars.

This result might have been expected from a knowledge of a

* However even in impact tests at normal temperatures there is a tendency to elongate and rupture near the ends of the bars, rather than at the center.

fact which has been determined experimentally, namely, that the effect of low temperature is to raise the elastic limit of metals. Now it is another well-known fact that when two materials are placed in conjunction, one of which is rigid and the other a cushion, that the more rigid material will quickly transfer the strain-energy to the cushion where it is absorbed. For instance, the function of the hardened face of an armor plate is to transfer the energy of

TABLE XII.—COMPARISON OF RUPTURE-WORK OF STEEL CASTING, 2-INCH GAGE LENGTH, AS OBTAINED FROM ACTUAL TEST AND COMPUTED FROM FORMULA.

HARD CASTINGS.

Number of heat.	Rupture-work in ft. lbs. per cu. in.		Fracture.	Per cent of elongation under gradual test.
	Test.	Formula.		
414	790	834	Rough crystal	14.7
497	697	667	Irregular	13.1
397	992	841	Crystal	14.5
338	1,092	1,040	Square dull	11.0
	900	925		14.8
	664	640		15.0
30	548	604		12.5
	665	640		15.0

SOFT CASTINGS.

467	1,488	1,390	Fibrous	32
534	890	860	Granular	22
	957	1,008		21.7
485	775	974	Rough fiber	20
573	1,794	1,770	Fibrous	33
420	1,344	1,370		28.5
468	1,444	1,392	Silky	31.5
462	1,048	1,040	Crystal	24
428	963	963	Silky	37
420	1,344	1,370		28.5

the projectile quickly throughout the metal of the face to the soft back where it is absorbed without breaking the plate. The effect noticed in the author's experiments may thus be explained by the assumption that the colder portions of the bar were transformed, in effect, to a metal of a higher elastic limit, which had the property of transferring the strain-energy to the warmer portions of the bar. This frozen portion, therefore, did not suffer any elongation. The total rupture-work was of course less than that obtained from a

bar which was entirely warm, for the reason that there was less metal undergoing deformation. The energy has to be absorbed somewhere in the bar, and where the entire bar is cold there is less capacity for absorbing shock up to rupture. However, a cold bar should withstand ordinary shocks of service within the elastic limit with a greater factor of safety since the effect of low temperature is to raise the elastic limit.

It must be recognized that the laws shown in Figs. 10 to 13 should be modified by magnifying the variations there shown, for

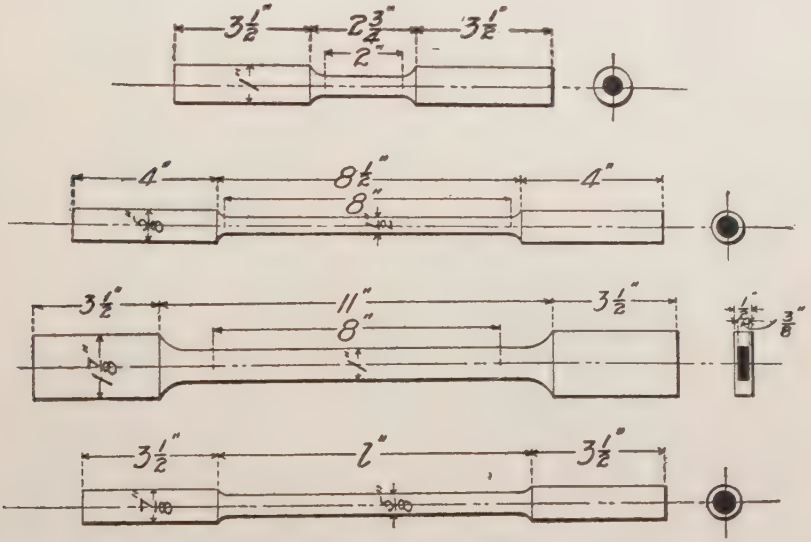


FIG. 14.

the reason that the temperature of the test bars under the freezing mixtures was not uniform, but that the full weakness due to the temperature was somewhat reduced by the higher temperature of the ends of the bars. The exact reductions the author is unable to estimate.

To meet the criticism that the decrease in elongation at low temperatures is mainly due to the fact that the bars did break at the end and not to the effect of low temperatures, the writer examined the relative elongation of bars broken at normal temperatures in the middle third of gage length, and at the ends.

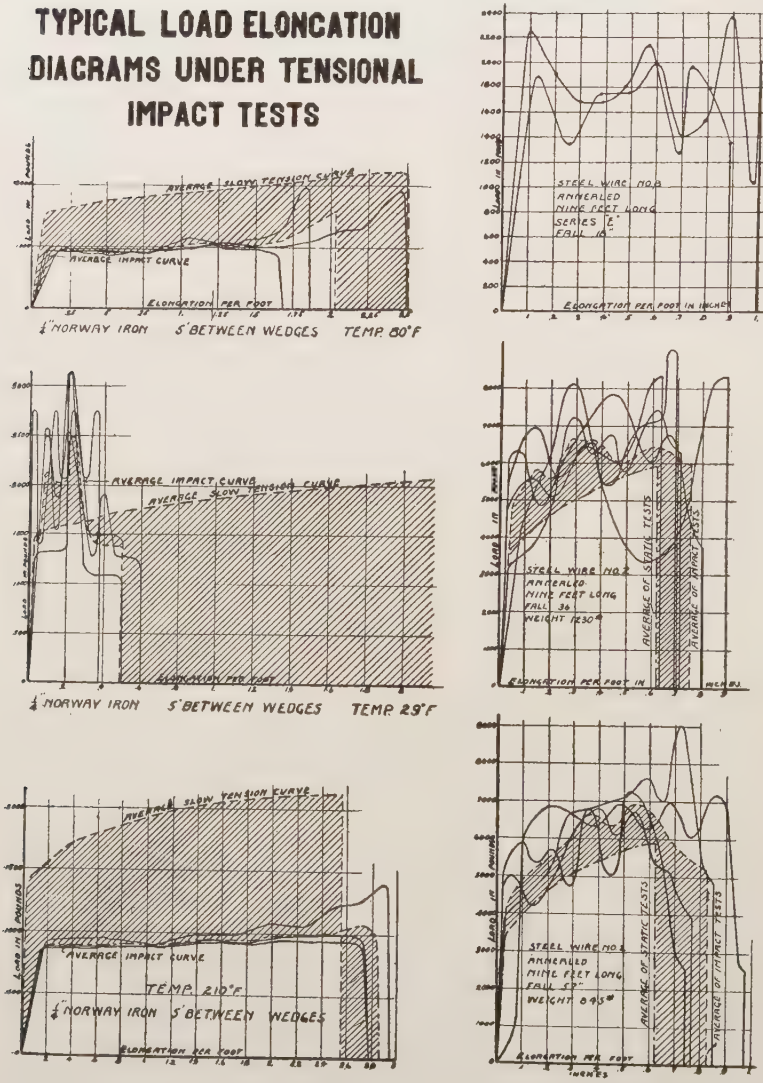

TYPICAL LOAD ELONGATION DIAGRAMS UNDER TENSIONAL IMPACT TESTS
AVERAGE SLOW TENSION CURVE
AVERAGE IMPACT CURVE
ELONGATION PER FOOT
¼" NORWAY IRON 5' BETWEEN WEDGES TEMP. 80°F
STEEL WIRE NO. 8 ANNEALED NINE FEET LONG SERIES E FALL 18"
ELONGATION PER FOOT IN INCHES
AVERAGE IMPACT CURVE
AVERAGE SLOW TENSION CURVE
¼" NORWAY IRON 5' BETWEEN WEDGES TEMP. 29°F
STEEL WIRE NO. 8 ANNEALED NINE FEET LONG FALL 36" WEIGHT 1230#
AVERAGE OF STATIC TESTS
AVERAGE OF IMPACT TESTS
ELONGATION PER FOOT IN INCHES
AVERAGE SLOW TENSION CURVE
AVERAGE IMPACT CURVE
TEMP. 210°F
¼" NORWAY IRON 5' BETWEEN WEDGES
ELONGATION PER FOOT
STEEL WIRE NO. 8 ANNEALED NINE FEET LONG FALL 57" WEIGHT 845#
AVERAGE OF STATIC TESTS
AVERAGE OF IMPACT TESTS
ELONGATION PER FOOT IN INCHES

Fig. 15.

Thus, the average per cent of elongation when broken at the center was 29.6; and when broken at the ends, 26.4 per cent. The elongation at —100° F. was 8 per cent. About one-half of the number of bars broken at 70° ruptured near end gage mark. Thus, the decrease in elongation in Fig. 13 is evidently too large to be accounted for by the location of the fracture. Table X gives the elongation at fractured inch of gage length as affected by temperature.

Condition of Surface and Shape of Cross-Section.—The author had planned a series of tests to determine the relative properties of bars, some of which were to be polished, others rough, others rasped, etc. Another series was to include bars of rectangular square and circular cross-section, all of the same area. It seems reasonable to suppose that the phenomenon of the flow of metals under high rates of distortion must be influenced very largely by the shape of the cross-section and the condition of the surface.

The experiments were not completed, but a series of boiler-plate test bars was tested with the results shown in Table XI. The bars were selected from a large number of specimens so as to be as nearly as possible of the same quality as shown by the test reports from the mill. The results of these tests are not, in the author's opinion, conclusive, but they show indications. For instance, polishing the bars did not cause any large increase in ductility over a bar with ordinary mill surface. When a bar, however, is taken rough from the first cut in the milling machine, the strength is less than a bar that has been given a finishing cut. The nicked bars, of course, had but very little strength.

Views of shape of test bars are shown in Fig. 14.

STAYBOLT IRON AND MACHINE FOR MAKING VIBRATORY TESTS.

By H. V. Wille.

Introduction.—The question of staybolt maintenance is one of the most serious questions with which motive power officials have to contend, and all kinds of efforts have been made to overcome the difficulty. The high pressure and large boilers now universally used in American locomotives have greatly increased the difficulty experienced with the breakages of bolts and have given rise to many devices to prevent such failures.

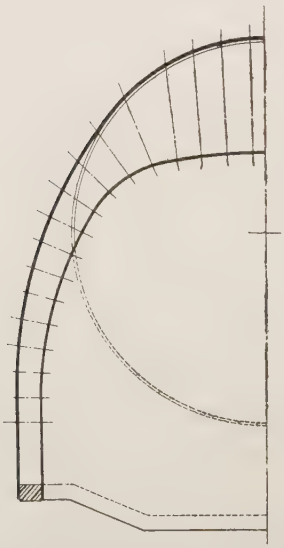


Fig. 1.

Causes of Staybolt Failures.—It may be well to explain to those who are not familiar with locomotive boiler construction that a staybolt is used to stay the flat surfaces of the boiler, as shown in Fig. 1. The bolts are usually from $\frac{7}{8}$ inch to $1\frac{1}{8}$ inches in diameter and are screwed into the two sheets and riveted over.

The two principal difficulties experienced are (1) Leakage, (2) Breakage; but as this article is to refer more particularly to the proper material and a rational method of testing than to the general subject of staybolts, the second difficulty will only be referred to.

The breakages are caused by the vibration resulting from the unequal expansion of the inside and outside sheets. This reason is well understood and led to the introduction of the flexible staybolt.

Flexible Staybolts.—The object of this device, shown in Fig. 2, is to provide for the vibration of the sheets. It usually consists of:

1. A sleeve which is screwed into the outside sheet.
2. A staybolt with a ball end to fit into a socket in the sleeve.

3. A cap to make the socket steam-tight.

Devices of this kind have not proved altogether satisfactory for the reason that with incrusting waters it will be but a short time when the ball joint will become filled with scale and will thus become as rigid as the ordinary screwed stays. They are also expensive both to apply and to maintain, and usually give more trouble from leakage than the ordinary stay because the thread in the firebox side is apt to be stripped in driving, inasmuch as there is less support for holding on; and because of the tendency to drive them when in service without taking off the caps so as to enable the workman to hold on to the bolt. In short, the experience of those using staybolts of this nature has not been such as to encourage the general adoption of any device of this kind.

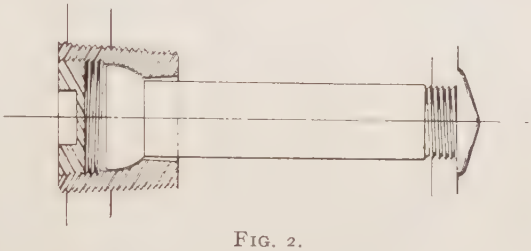


FIG. 2.

Dimensions of Bolts.—Designers have been endeavoring to reduce the failures to a minimum by increasing the length of the bolts and by decreasing the diameters. A consideration of the causes leading to the breakage of bolts will show that there are several reasons why a $\frac{7}{8}$ inch bolt should give a longer life than the 1 inch bolt, notwithstanding the fact that it has a smaller area. The firebox expands and contracts to an extent depending upon its size and the variations in temperature to which it is subjected. The staybolts are thus not loaded to a definite fiber stress (in which case the bolt of larger diameter would be the more serviceable), but they are deflected through a given angle, and the amount to which they are deflected cannot be altered by any increase in strength or in diameter. The angle through which the axis of the bolt is bent being independent of the diameter of the bolt, as indicated in Fig. 3. the outer fiber of the large bolts will be stretched to a greater amount than the outer fiber of the smaller bolts, and a crack will thus start sooner in the 1 inch bolt than in the $\frac{7}{8}$ inch bolt. After the bolt starts to crack, it is very short-lived. It would appear that the

bolt with the smaller diameter will be in service a longer time before starting to crack than the bolt of larger diameter, but the time between the starting of the crack and the breakage of the bolt will be greater for bolts of the larger diameter. This time is but a small proportion of the total life of the bolt, and the bolt that remains in service the shortest time after a crack is once started is the more desirable bolt, for after it is cracked the sooner it is removed, the better.

FIG 3.

A cable composed of a large number of strands will bend and twist a great number of times without breaking, although the tensile strength is very much less than the strength of a solid bar of the same diameter. The nearer we approach to this condition in boiler design, the less trouble we will experience. In line with this experience, boilers have been built with bolts of $\frac{3}{4}$ inch diameter, but the bolts were spaced more closely than is usually the practice.

The small bolts also have an advantage in heading, for the hard hammering necessary to head a bolt of large diameter or of hard iron is liable to strip the thread of the bolt. Bolts of smaller diameter will not require heavy hammering and will therefore probably give less trouble from leakage than is experienced with bolts of larger diameter. Futhermore, the head of the bolt of smaller diameter would not be heated to as high a temperature as the bolt of larger diameter, because it is more readily cooled by the water. For this reason as well as because of its smaller diameter, it would not expand as much. The metal in the bolt expanding enlarges the hole in the sheet, putting a permanent set in it, causing the bolt to leak; and from what has been said, it is obvious that the effect of this is less, the smaller the diameter of the bolt. Another advantage in the use of the bolts of smaller diameter is that they can be replaced a greater number of times without unduly increasing the diameter of the bolts. This is an important structural advantage and in

the end would no doubt prove economical because the life of the firebox would be increased. The future will probably see the more general adoption of the $\frac{3}{4}$ inch bolt with closer spacing, but the present practice of using a $\frac{7}{8}$ inch bolt is a happy medium between the most advanced and most conservative practice.

Let f = Fiber stress.
E = Modulus of elasticity.
I = Moment of inertia.
d = Diameter.
l = Deflection
L = Length.
W = Load.

From the usual formula for flexure we have:—

1. $W = \frac{2f}{d} \frac{I}{L}$
2. $l = \frac{W L^3}{3E I}$ substituting 1 in 2
3. $l = \frac{2f}{3E} \frac{L^2}{d}$ then
4. $f = \frac{3E}{2} \frac{d l}{L^2}$

This shows that the extent to which the bolt is strained increases in direct proportion to the diameter and decreases as the square of the distance between the sheets. Applying the formula in actual practice, assuming as a basis in our calculation a staybolt of 1 inch in diameter and deflection of $\frac{3}{100}$ inch and a distance between sheets of 6 inches, we find that the bolt is strained to a fiber stress of 35,000 pounds per square inch. If the diameter is reduced to $\frac{3}{4}$ inch the staybolt is strained to but 26,250; by decreasing the distance between the sheets to 5 inches the bolts are strained to 50,400 for the 1 inch, and 37,700 for the $\frac{3}{4}$ inch. These results show very clearly the cause of staybolt breakage and what should be done in order to reduce the trouble to a minimum, namely, make the water space as wide as possible and use a small bolt with a closer space if necessary.

Specifications and Material.—Some few railroads have recently specified a very high tensile strength for staybolt iron; and the question arises, is the tensile test a proper one upon which to rate staybolt iron? If a member is subjected to a direct tensional strain or a definite load in pounds, then a high tensile strength or elastic limit is desirable because it gives a high factor

of safety. If, however, a member is subjected to a definite *deflection*, then the stiffer the iron, the greater the load necessary to produce this deflection. In other words, a high tensile bolt is subjected to a higher fiber stress than a soft low tensile bolt. It is for this reason that steel gives excellent results in such parts, axles for instance, as are loaded to a definite fiber stress, but will not answer for staybolts which are bent through a given angle.

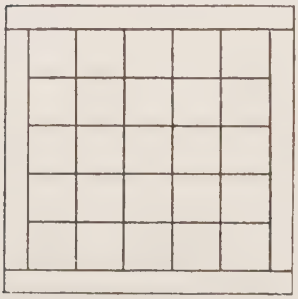


FIG. 4.

The manner in which the iron is piled and rolled plays a far more important part upon the life of the bolt than the tensile strength; and after many experiments, those who have given the subject much thought have decided upon a fagoted bar piled iron. A diagram of this piling is shown in Fig. 4. The central core is composed of a number of bars, approaching in appearance a bundle of wires. This core is enclosed by an outside sheath of metal with circular fibers. This ensures a good thread and prevents the bolt being strained in a direction at right angles to the fibers.

A soft ductile iron piled in this way will undoubtedly give better results than a hard tensile iron piled in the usual slab form, shown in Fig. 5. Staybolt iron made in this manner may be strained by bending in a direction at right angles to the fibers and would then have a very short life.

FIG. 5.

This matter has been thoroughly demonstrated by making vibratory tests of various makes of staybolt iron, and the results obtained in the vibratory machine have been confirmed by practice. The writer's attention has recently been directed to a marked difference in the life of staybolts on two groups of engines of

precisely the same design and in operation on the same division. Upon investigation it was found that a very high priced special brand of high tensile staybolt iron was used in the engines with which trouble was being experienced, while a good grade of well-piled soft and ductile iron was used in the engines which were giving good service.

For reference it may be well to give the tensile requirements of specifications which the writer has been able to gather:

ROAD.	Tensile.	Elongation.
Atchison, Topeka and Sante Fe	48,000	28 per cent.—8″
Baltimore and Ohio	48,000	25 " —8″
Chesapeake and Ohio	48,000	25 " —2″
Burlington and Missouri River	48,000	30 " —2″
Chicago, Burlington and Quincy	49,000	28 " —8″
Lehigh Valley	50,000	30 " —4″
Missouri Pacific	47,000	26 " —8″
Mexican Central	48,000	25 " —8″
New York Central and Hudson River	48,000	28 " —8″
Norfolk and Western	48,000	25 " —8″
Pennsylvania Railroad	48,000	25 " —8″
Philadelphia and Reading	46,000	45 " —2″
Seaboard Air Line	48,000	25 " —8″
Southern Railway	52,000	28 " —8″
Harriman Associated Lines	52,000	28 " —8″

It will be seen from the above that it is almost the universal practice to specify a 48,000 tensile iron, it being generally realized that an iron is thus secured which is sufficiently strong, which will take a good head without an amount of hammering that is liable to strip the thread and which will successfully withstand the alternate bending it encounters in service.

Vibratory Machine.—No one will gainsay that a staybolt should be tested in a manner similar to which it is strained in service. Some years ago this matter was thoroughly agitated, and a large number of experiments were made with makeshift apparatus. The results varied widely, largely because of the different methods of holding the bolt and because the bolts were vibrated in one plane. Very good results would be obtained if the bolt chanced to be vibrated in a plane parallel to the direction of piling, while very poor results would follow vibrating such a bolt at right angles thereto. The matter has been taken up with Mr. Tinius Olsen and he has designed the most complete

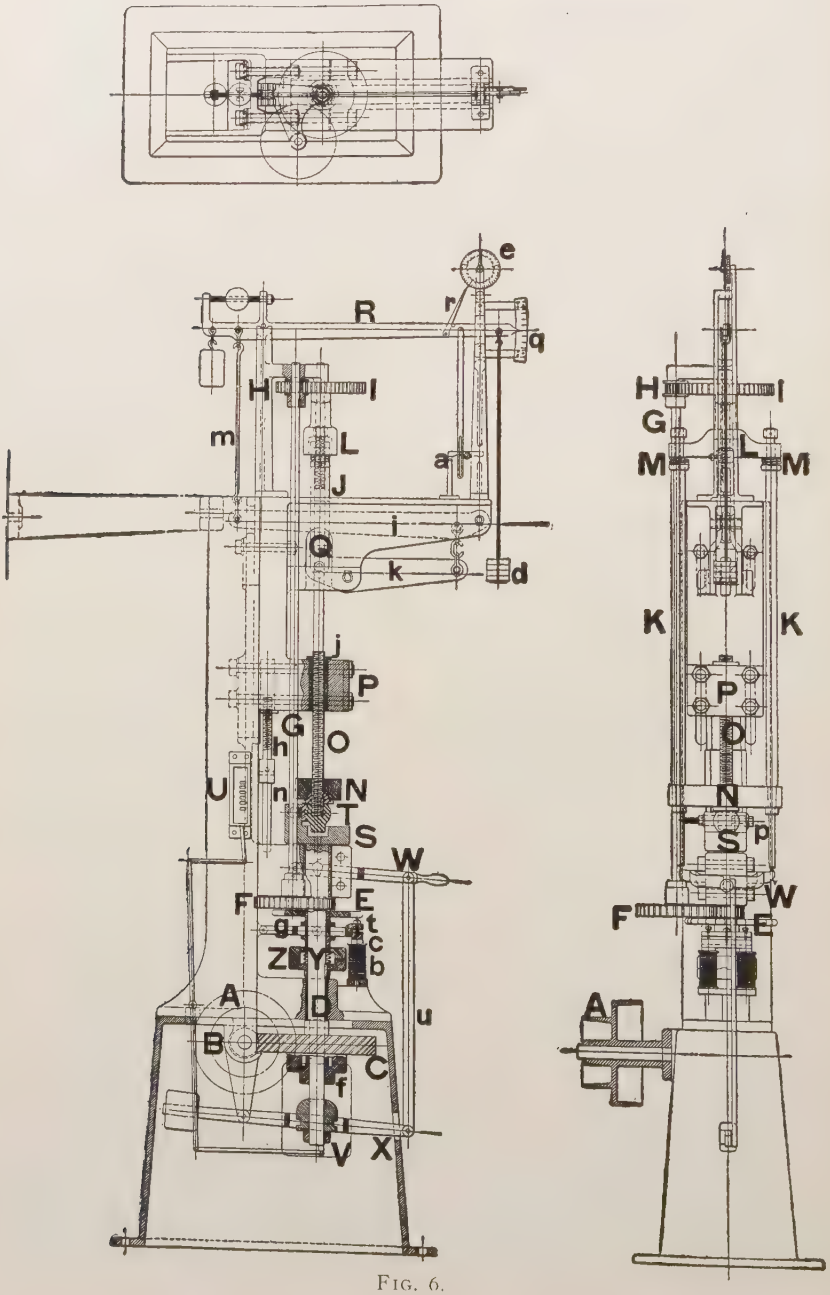

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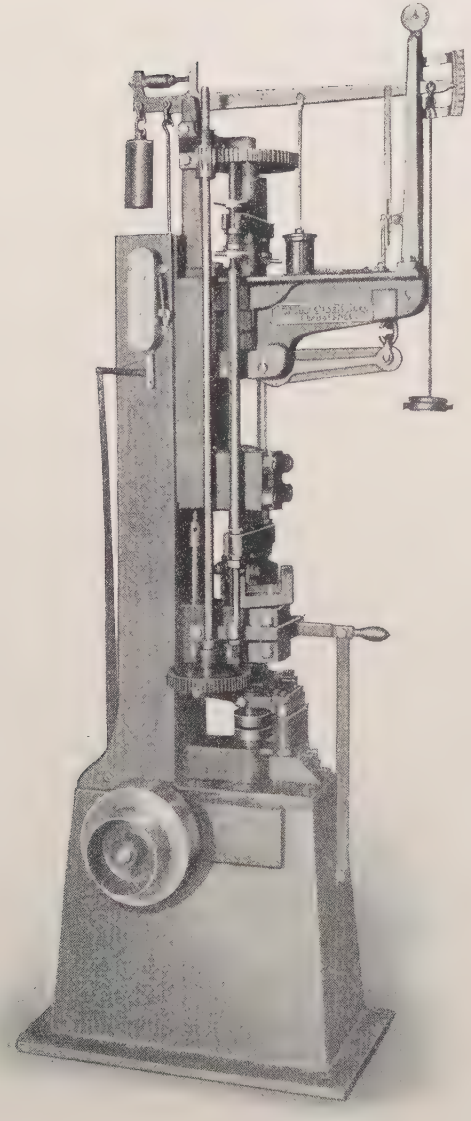
FIG. 6.



MACHINE FOR MAKING VIBRATORY TESTS.

and satisfactory machine which has yet been proposed for staybolt testing.

The purpose of the machine is to record the number of vibrations of a given amplitude which a test bar will withstand. It is especially adapted to the requirements of staybolt testing and will accommodate staybolts from 5 to 8 inches in length. The upper end is held rigidly while the lower end is given a circular vibratory motion which can be adjusted from zero to a circle of $\frac{3}{8}$ inch in diameter.

The following description shows the mechanism and operations of the machine:

The Power Mechanism.—The machine is provided with two speeds obtained by shifting the belt on the cone pulley *A*, Fig. 6. On the same shaft with the cone is a small spiral pinion *B* meshing with a large gear *C* which runs idle on the main shaft *D* when the machine is not in operation, and causes the shaft *D* to rotate when the clutch *f* is thrown in.

If it is desired to have several machines of this character, they may be built upon one base, sitting close together as the upper parts extend only a little over 6 inches on each side of the center line. In this case one cone pulley will be sufficient for all the machines; and its shaft, extending through the longer base, will operate the large spiral gear *C* for each machine. The shaft *D* therefore is the main shaft for each unit as it furnishes the power and movements necessary for all the operations.

The Loading Mechanism.—The shaft *D* carries a small idle pinion *E* which is secured to the loose sleeve *g*. It is thrown into operation by the clutch *Z* and drives the gear *F* on the vertical shaft *G*. This shaft in turn carries a small pinion *H* at its upper end which drives the screw *J* by means of the gear *I*. When this screw revolves it forces the crosshead *L* down upon two shoulders on the vertical rods *K K* which are situated inside of the spring coils *M M*. This puts a compression in the rods *K K*. The lower crosshead *N* transfers this force from the two vertical rods onto the staybolt *O*, producing a tension in the bolt. The lower end of the staybolt is fastened in the crosshead *N* by a ball-and-socket joint, while the upper end is held rigidly by means of the head *P* which attaches to the frame of the machine. This head *P* is a large and rigid

casting which is fastened to the frame by the four bolts shown, and carries the entire scale apparatus. It can be adjusted vertically to accommodate different lengths of test pieces by loosening the six bolts and turning the adjusting screw *h*. The shaft *G* is fitted to the pinion *H* by a loose key to allow of this adjustment, and the pinion is supported by a housing which extends over the face of the gear *I*. The staybolt is secured in the head *P* by a steel bushing *j* which is split in two parts and threaded to correspond to the staybolt. The lower ball joint and also the ball *T* are tapped out to correspond to the staybolt.

The Weighing Mechanism.—When the screw *J* puts a compressive force in the two rods *K K*, its reaction is taken up by a tensile force acting through the clevis *Q* which communicates to the scale-beam *R* through the levers *k* and *i* and the rod *m*.

The Vibratory Mechanism.—On the upper end of the main shaft *D* is a head *S*. This is fitted with an adjustable bearing *n* which sets against the ball *T*, screwed on the lower end of the staybolt. The adjustable bearing can be set eccentric with the head so that the staybolt will have a circular vibratory motion when the head *S* revolves. This eccentricity is obtained by setting up a wedge, back of the bearing *n* by means of the bolt *p*. The ball joint in the crosshead *N* and the one on the lower hub boss of the gear *I* furnish the necessary flexibility to take up these vibrations.

The Counting Device.—A revolution-counter is placed at *U* which registers the number of vibrations of the staybolt, being operated by a linkage attached to the pin *V*. If the staybolt breaks, the springs *M M* force the vertical rods *K K* down. The lower ends of these rods thus come in contact with the lever *W* which communicates the motion to the clutch lever *X* by means of the link *u*, thus disengaging the clutch which stops the shaft *D* and with it the revolution-counter.

The Automatic Electrical Mechanism.—The spring at *Y* tends to keep the clutches at *Z* separated, thus allowing the loading mechanism to become inoperative. If the staybolt stretches, the scale-beam *R* will fall, causing electrical contact at *a*. This closes the circuit, causing the magnets at *b* to draw down the armature *C*, thus throwing the clutch *Z* into operation. This will start the loading mechanism, which will continue to run until the stretch of the staybolt is taken up and the scale-beam

rises to its highest or zero point and breaks the contact at *a*, thus allowing the clutch at *Z* to again disengage.

The ratio between the movement at the staybolt and at the end of the pointer on the beam *R* is 1 : 500. The arc *q* is 5 inches long; therefore, if the staybolt stretches $\frac{1}{100}$ of an inch the beam will fall from the top to the bottom of the arc. Then the adjustment will take place and the beam rise again. When it reaches the top, the small pointer *r* engages a tooth of the recording disc *e*, moving it one notch. Thus the divisions on the disc *e* represent the stretch of the staybolt in hundredths of an inch. The arc *q* is divided into ten parts. Each division, therefore, represents $\frac{1}{1000}$ of an inch stretch of the staybolt. By observing the stretch as shown on this scale and the corresponding vibrations as given by the counter, the number of vibrations required to produce a stretch of $\frac{1}{1000}$ of an inch in the staybolt may be obtained.

The amount of load which shall be kept on the staybolt is predetermined by the number of weights at *d*. The load is first applied by the hand wheel which is fast on the sleeve *q*.

Standard Vibratory Tests.—It is very important to standardize the various requirements. It is the present practice to thread the bolts the entire length in the ordinary staybolt dies. This would seem to be undesirable, as there may be some variation in diameter and the results would be affected by the condition of the die. It would seem desirable:

a. To notch the test piece with a single V-shaped groove of a standard staybolt thread to a diameter corresponding to the diameter at the base of the thread.

b. To specify the speed of the machine, *i. e.*, the number of vibrations per minute.

c. To specify the length of the bolt between clamps.

d. The tensile load upon the bolt. This load should be so applied that it will not fall off when the bolt stretches.

With these conditions specified it is probable that results on one machine can be duplicated upon another of different make. This has hitherto been the chief obstacle in the way of the adoption of a vibratory test for staybolts, and the excellent design of the Olsen machine would seem to effectually overcome the difficulty.

BENDING MOMENTS IN RAILS.

By P. H. Dudley.

The wheel effects of the passing locomotives are resolved into negative and positive bending moments by the section of the rail when depressed from its unloaded position in the "trackman's surface" to its loaded condition of the running surface in the "General Depression." From a continuous beam resting on numerous cross-ties as flexible supports in the ballast, and the latter upon a compressible subgrade, the rail section by the progressive loading of the passing locomotive is converted into a "constrained beam," strengthened and stiffened to carry and distribute the driving wheel loads and the expended tractive effort.

The cross-ties as flexible supports, depressing more directly under the wheels than in the wheel spacing, do not control the span of the bending rail, as generally supposed.

The wheel spacing and the wheel loads, loading the rails at intervals of two or three cross-ties, become the more important factors in fixing the span of the bending rails, per wheel, causing the negative and positive bending moments of the wheel effects in the "General Depression." When the rail section is well spliced and stiff it may be, by parts of the load of the locomotive, strengthened and stiffened for carrying and distributing the driving wheel loads and expended tractive effort.

This favorable action of the rail section as a beam loaded in the "General Depression," *unique in Mechanics*, is in part due to the flexible supports upon which it is depressed by the several wheels of the subdivided total load, each wheel load causing conjoint strains in the metal of the section, which assists to check deflections under adjacent wheels. The foundation is also favorably loaded and restricted in its movements.

A single pair of wheels in a long wheel spacing, independent of the conjoint action of other wheels on the rail, has a limited "General Depression," confined to one specific deflection under the

wheel. The looseness of the track not being reduced by preceding wheels, the positive bending moment is constrained only by the superstructure, instead of adjacent wheel loads.

The above brief statements are for the purpose only to call attention to one or two relations of the many problems of the rail section as a girder, in carrying and distributing the load of passing locomotives to the foundation or subgrade, as indicated by the bending moments.

For the Sixth Annual Meeting the author presented Stremmatograph tests of the unit fiber strains in rails in detail, under Locomotive No. 870, drawing the Empire State Express, on the New York Central & Hudson River Railroad. On the same dates and location, similar tests were made under all "out-bound" trains, until 2 p. m. of each day. Two types of engines, an 8-wheel and a 10-wheel, were drawing through passenger trains. The tests furnished the means of comparing the sums of their relative negative and positive bending moments in the same rail, and other parts of the superstructure, as determined from the recorded and measured unit fiber strains of the passing wheel effects.

The bending moments of Tests Nos. 257 and 271, of Locomotive No. 870, are given in the aggregate, as the unit fiber strains were previously published. The bending moments from the unit fiber strains of Test No. 269, the 10-wheel engine drawing the Southwestern Limited, are presented in detail for the unit fiber strains per wheel, which will be sufficient to illustrate the general method of ascertaining the results. In Tests Nos. 257 and 271 the total static load of the locomotive was 220,000 pounds, drawing a train of four cars, total weight of 430,000 pounds. In Test No. 269, the total static load of the locomotive was 282,900 pounds, drawing a train of nine cars weighing 910,000 pounds—over twice as heavy, yet with its closer wheel spacing of the engine, the inch-pounds of the positive bending moments were less per pound of static load, and were constrained by more efficient bending moments. In other words, the foundation or subgrade was more favorably loaded by the 10-wheel type of engine.

These tests confirm the American theory and practice of the importance of distributing the wheel loads by well-designed wheel bases in the locomotives.

The average inch-pounds per pound of static load for one rail

of Engine No. 870, on December 23 and 30, was 12.40 inch-pounds. For the 10-wheel engine it was 10.80 inch-pounds—quite a percentage in favor of the larger engine, due to the closer wheel spacing for the weight of the rail. The total positive bending moments for locomotive No. 870 on the two dates are nearly alike, being 11.46 and 11.50 inch-pounds per pound of static load. For the 10-wheel engine, Test No. 269, the positive bending moment for the wheels in good condition was 9.82 inch-pounds per pound of static load. Under the Consolidation type of locomotives drawing freight trains, even more favorable comparisons are obtained. With the 12-wheel type of freight engines the results are still more favorable as to the distributed load through the rail section, in loading the foundation.

The details of the tests show the negative bending moments occur in the wheel spacing, and constrain the positive bending moments which are nearly or directly under the wheels.

At the points of flexure in the rail section shearing strains in the web connect the negative and positive bending moments between and under the wheels, making the action of the metal of the rail section continuous in the "General Depression" for the entire wheel base of the locomotive, and under the first truck of the passenger coaches.

In the freight service, with the 60,000, 80,000 or 100,000 pounds capacity cars, with an inside wheel spacing of 18 to 20 feet only, the "General Depression" is continuous for the entire train length.

The magnitude of the constraining negative bending moments in the wheel spacing for a given unit fiber strain, under the positive moments, depends upon the stiffness of the rail section and looseness of the track, the latter being one of the variables in the permanent way. A closer comparison is more easily made between the unit fiber strains of the negative than of the positive bending moments.

In 4½-inch 65-pound rails, under Switching Engine No. 1, Grand Central Station, New York, having 125,000 pounds upon three pairs of drivers, the unit fiber strains for the negative moments ranged from 1,800 to 2,500 pounds for the unit fiber strains of 30,000 to 45,000 pounds under the wheels. On the 6-inch 100-pound rails, for similar unit fiber strains for the negative moments the positive bending moments only had unit fiber strains

varying from 6,000 to 8,000 pounds, the ratio of constraint being many times greater.

Limber rails have large unit fiber strains, but carry only small negative bending moments, and are also limited in the positive bending moments which they can sustain without exceeding the elastic limits of the metal. As the stiffness of the rail increases, with the same unit fiber strains, larger bending moments are carried by the rails in distributing the wheel loads to the cross-ties, ballast, and the subgrade.

While it is easy by the construction of the wheel base of the locomotive to distribute a large total load on a stiff rail, the intensity of the pressure between the wheel contacts and the head of the rail is increased by the heavy axle loads. The metal in our present rails under the rolling wheel contacts has much more work to do than was the case with the lighter wheel loads and more limber rail sections.

The same physical properties which sustained the light wheel loads for a large tonnage, show a greater rate of wear under the present wheel loads.

The increased work of the stiffer rails and doubled wheel loads, with larger expended tractive power of the engines, should receive the attention and consideration it deserves, for our present service.

Test No. 257.—R. C. Reduction of sum of positive and negative bending moments to one pound of static load, for one rail:

Engine,	Sum of positive bending moments,		821,245.00	in.-lbs.
"	"	P. B. M. per pound of static load,	12.65	"
"	"	negative bending moments,	125,234.00	"
"	"	N. B. M. per pound of static load,	1.92	"
Tender,	"	positive bending moments,	438,911.00	"
"	"	P. B. M. per pound of static load,	9.75	"
"	"	negative bending moments,	63,279.00	"
"	"	N. B. M. per pound of static load,	1.40	"
Locomotive,	"	positive bending moments,	1,260,156.00	"
"	"	P. B. M. per pound of static load,	11.46	"
"	"	negative bending moments,	188,513.00	"
"	"	wheel effects,	1,448,669.00	"
"	"	N. B. M. per pound of static load,	1.71	"
First Car,	"	positive bending moments,	663,576.00	"
"	"	P. B. M. per pound of static load,	12.52	"
"	"	negative bending moments,	141,187.00	"
"	"	N. B. M. per pound of static load,	2.66	"
"	"	wheel effects,	804,763.00	"

Weight of one-half of car, 53,000 pounds.

The negative bending moments in the wheel spacing constrain and check the positive bending moments under the wheels, a decided advantage.

Test No. 271.—R. C. Reduction of the sum of positive and negative bending moments to one pound of static load, for one rail:

Engine,	Sum of positive bending moments,		788,948.00	in.-lbs.
"	"	P. B. M. per pound of static load,	12.15	"
"	"	negative bending moments,	121,170.00	"
"	"	N. B. M. per pound of static load,	1.85	"
Tender,	"	positive bending moments,	479,276.00	"
"	"	P. B. M. per pound of static load,	10.59	"
"	"	negative bending moments,	67,304.00	"
"	"	N. B. M. per pound of static load,	1.49	"
Locomotive,	"	positive bending moments,	1,268,224.00	"
"	"	P. B. M. per pound of static load,	11.50	"
"	"	negative bending moments,	188,474.00	"
"	"	N. B. M. per pound of static load,	1.71	"
"	"	wheel effects,	1,456,698.00	"
First Car,	"	positive bending moments,	710,868.00	"
"	"	P. B. M. per pound of static load,	13.39	"
"	"	negative bending moments,	95,587.00	"
"	"	N. B. M. per pound of static load,	1.80	"
		Wheel effects,	806,455.00	"
		Weight of half of car, 53,000 pounds.		

The average of the positive and negative moments for the locomotive are less than for the engine of the 8-wheel type, as a rule, for about the same speed as the tests. The effect of the load upon the forward truck decreases slightly as the speed increases, while that upon the driving wheels is augmented, particularly the positive moments.

In comparing the details of tests Nos. 257 and 271 by the sum of the positive or negative bending moments per pound of static load, either under the engine or tender, slight differences are to be expected, for neither the engine nor tender can distribute its load through the wheel contacts independently one from the other. The equalizing of their loads on the rails in the track occurs conjointly as the total load of the locomotive, at least before irregular dynamic forces are generated, by one or more pairs of wheels. See Test No. 269.

Dynamic forces will be generated by all the wheels as the speed is augmented, the law of the increase being unknown.

To compare the tests critically, the total sum of the wheel

NEW YORK CENTRAL AND HUDSON RIVER RAILROAD

P. H. Dudley's Stremmatograph Tests December 23, 1899.

No. 269. Track No. O. Location, 6° curve 600 feet west of Mile Post No. 10.
Rail 5½ inch, 80 lbs. Moment of Inertia 28.4 equivalent 4th Power inches.
Cross-ties. Length 8′. Width 9″. Thickness 6″. Wood Y. P. Weight 155 lbs.
No. 18 per 30 feet rail. Average weight of superstructure per yard 449 lbs.
Three-tie supported joints, 36 inch splice bars, Stone ballast.
Train No. 11. No. of cars 10. Weight 910,000 lbs.
Locomotive No. 2032. Weight 282,900 lbs. Speed 40 miles per hour. Temperature 40° F.
Remarks, Engine Class F, 3 A.
The apparent mean extreme unit fiber stresses in the base of one rail were as follows in pounds:

	First C. W. down over Stremmatograph. Second C. W. nearly up over Stremmatograph. Third C. W. last quarter down.	Per wheel.	Per wheel base of: Drivers and trucks of engine, tender and cars.	Per wheel base of: Engine and tender.	Per wheel base of: Locomotive and cars.	Per lb. of wheel base of: Drivers and trucks of engine, tender and cars.	Wheel effects: Positive bending moments under wheels inch-lbs.	Wheel effects: Negative bending moments between wheels inch-lbs.
	Extra wave preceding truck wheel.							
	Compression in front of truck wheel	1,417						16,154
LOCOMOTIVE Engine Truck	° Tension under front truck wheel	12,519					142,717	
	Compression between front and rear truck wheel	236	19,487			0.962		2,690
	° Tension under rear truck wheel	3,071					35,009	
	Compression between truck wheel and front driver	4,487						51,152
Engine Drivers	° Tension under front driver	25,744		96,249			293,482	
	Compression between front and main drivers	3,779						43,081
	° Tension under main driver	21,022	76,762			1.193	239,651	
	Compression between main and rear drivers	4,487						51,152
	° Tension under rear driver	17,715			169,118		201,951	
	Compression between rear driver and front tender wheel	3,543						40,390
Tender F. T.	° Tension under front tender wheel	11,574					131,944	
	Compression between tender wheels, front truck	3.071	29,290			1.065		35,009
	° Tension under rear tender wheel, front truck	12,519					142,717	
	Compression between front and rear tender trucks	709		72,869				8,083
Tender R. T.	° Tension under front tender wheel rear truck (shocks)	23,620					269,268	
	Compression between wheels of rear tender truck	236	43,579			1.580		2,690
	° Tension under rear tender wheel (shocks)	17,715					201,951	
	Compression between tender wheel and first car wheel	3,307						37,700
First Car Front Truck	° Tension under front wheel of first car	8,503					96,934	
	Compression between first and middle wheel	236						2,690
	° Tension under middle wheel	8,976				.....	102,326	
	Compression between middle and rear wheel	2,362	30,469	.....				26,926
	° Tension under rear wheel	7,322					83,470	
	Compression back of wheel	1,417						16,154
	Compression in center of wheel space	0			85,386		0	
	Compression in front of wheel of rear truck	1,653						18,844
First Car Rear Truck	° Tension under front wheel of rear truck	10,393					118,480	
	Compression between front and middle wheels	709						8,083
	° Tension under middle wheel (shocks)	22,911	54,917	.....		.....	261,185	
	Compression between middle and rear wheel	709						8,083
	° Tension under rear wheel (shocks)	17,006					193,868	
	Compression between trucks of first and second cars	3,071						35,009

effects of either the locomotive or car must be used; for example, the sum for the locomotive in Test No. 257 was 1,448,669 inch-pounds, and in Test No. 271 it was 1,456,698 inch-pounds, a difference of 8,029 inch-pounds, which checks closely for the difference of the unit fiber strains between the tests.

Test No. 269.—R. C. Reduction of sum of positive and negative bending moments to one pound of static load, for one rail:

Engine,	Sum of	positive bending moments,	912,810.00	in.-lbs.
"	"	P. B. M. per pound of static load,	10.80	"
"	"	negative bending moments,	184,424.00	"
"	"	N. B. M. per pound of static load,	2.18	"
Tender,	"	positive bending moments,	745,913.00	"
"	"	P. B. M. per pound of static load,	13.08	"
"	"	P. B. M. per pound of static load for normal wheels,	8.36	"
"	"	negative bending moments,	84,827.00	"
"	"	N. B. M. per pound of static load,	1.48	"
Locomotive,	"	positive bending moments,	1,658,723.00	"
"	"	P. B. M. per pound of static load,	11.72	"
"	"	P. B. M. per pound of static load for normal tender wheels,	9.82	"
"	"	negative bending moments,	269,251.00	"
"	"	N. B. M. per pound of static load,	1.90	"
"	"	wheel effects,	1,927,974.00	"
First Car,	"	positive bending moments,	856,263.00	"
"	"	P. B. M. per pound of static load,	14.50	"
"	"	negative bending moments,	117,135.00	"
"	"	N. B. M. per pound of static load,	2.02	"
		Wheel effects,	973,398.00	"
		Weight of one-half of car, 58,000 pounds.		

The positive bending moments under the tender were increased by a minute roughness on the rear tender wheels, and the N. B. M. decreased. I have recorded what the results were, as that is an incident of practice, and also shown the results for normal wheels, but I have not introduced a correction for the negative bending moments. Two wheels were rough in rear truck of car.

THE DESIRABILITY OF UNIFORM SPEED IN COMMERCIAL TESTING.

By Paul Kreuzpointner.

During the past decade or more, particularly since the formation of the International Association for Testing Materials, and the American Society for Testing Materials, concerted action has become manifest, on the part of scientific and practical men, to put the knowledge of the properties and qualities of materials of construction, upon a comprehensive workable basis, and by combined efforts, give us a still better insight into the complex phenomena which daily confront the engineer and manufacturer in his business transactions.

However, while great strides have been made in our technical colleges, and by engineers generally, to perfect the methods and facilities for scientific investigation, and while the methods and facilities for the commercial testing of construction have likewise undergone considerable improvement during past years, there is still room for further perfection, and the perfection of methods in this respect is the more necessary, since the results of all scientific investigations are of little value, unless they can be made practically useful for the benefit of mankind.

In dealing with the commercial application and uses of large quantities of materials of construction, there is neither time nor often opportunity to ascertain the properties of the materials we are dealing with, and all we can do is to determine as nearly as possible the qualities desired by the engineer for a given purpose. In doing so, however, it is essential that the means and methods used to ascertain the qualities of materials, conform to the nature of the properties of the materials to be thus tested. If, for instance, the engineer decides upon a given degree of ductility as a safe factor for his structure, and we attempt to determine this degree of ductility by means of the usual methods and facilities for testing, it is not, and ought not to be, a matter of indifference whether, in

testing metals for instance, we give due consideration to the property of metals to flow under stress, and that it is the greater or less degree, or freedom, to flow, which determines the degree of ductility, which the engineer desires to ascertain.

Thus, since ductility is a function of that property of metals which we call plasticity, or its ability to flow, if, therefore, our method or methods of testing do not take into consideration this property of metals to flow under stress, then we impair, disturb or change the rate of flow, and consequently, our record of the degree of ductility obtained and expressed in per cent, is defective to that degree, as we have ignored the manifestations of the plastic properties of the metal we tested by our method or mechanical appliances.

In such a case we have recorded the mechanical efficiency of our appliances, but not the actual useful qualities of the metal the engineer is going to use. Hence, other things being equal, it is not so much the elaborateness and refinement of the appliances used in commercial testing which determines the reliability of a test, but it is the proper recognition, in connection with suitable appliances, of the properties of the materials and how their peculiarities may affect the qualities to be determined, while under test.

Speed of testing, the manner of preparing test pieces, and their shape, having considerable influence in the determination of reliable results, it is obvious that the greater the variations of these factors in the different laboratories with different materials, the greater the unreliability of general results and the less representative the qualities represented by the tests, are of the material tested. It may not be much in many cases, but it is a disturbing factor of unknown quantity.

This brings us to the point of the desirability of uniform speed of testing metals of construction. While we have now an approximately uniform test section, the next step for this Society to take would seem to be an endeavor to bring about a uniform rate of speed of commercial testing among producers and consumers, for the various structural materials used in engineering practice. To have steel tested at the rate of six minutes at one place, and the same steel at two or three minutes at another place, is neither scientific nor businesslike, although it may conform to our notion of personal liberty and independence. Most of the controversies which arose about the validity of rejections, during the more than

twenty-two years of my service in the Test Department of the Pennsylvania Railroad, were due to this question of speed in testing.

Being convinced that this question of the desirability of a uniform speed of testing deserves the attention of this Society, I would suggest the propriety of appointing a committee for investigation and report at the next annual meeting.

CAST IRON: STRENGTH, COMPOSITION, SPECIFICATIONS.*

By W. J. Keep.

The data which we have for this investigation consist of nineteen series of tests made for the Committee on Tests of the American Society of Mechanical Engineers in 1894–95, and of twelve series made in 1899–1901 by the Committee on Tests of the American Foundrymen's Association.

Each of these series consisted of pairs of test bars cast together varying in size from $\frac{1}{2}$ inch square to 4 inches square, and the latter with round bars of the same areas.

To compare such records of $\frac{1}{2}$-inch to 4-inch test bars it is necessary to find the strength of a section $\frac{1}{2}$ inch square by 12 inches long of each which is the greatest common divisor of all test bars. See Fig. 1.†

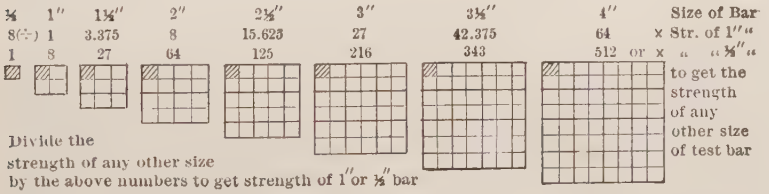

½ 1" 1½" 2" 2½" 3" 3½" 4" Size of Bar
8(÷) 1 3.375 8 15.625 27 42.375 64 × Str. of 1" "
1 8 27 64 125 216 343 512 or × " " ½" "
to get the strength of any other size of test bar
Divide the strength of any other size by the above numbers to get strength of 1" or ½" bar

Fig. 1.

Tensile tests were made by the American Foundrymen's Association.

Complete chemical analyses were made of each series.

The American Society of Mechanical Engineers series are numbered and the American Foundrymen's Association series are lettered.

* This paper was contributed jointly and simultaneously to the American Society for Testing Materials and the American Society of Mechanical Engineers.—W. J. K.

† Acknowledgment is made to the American Society of Mechanical Engineers for the cuts used in this paper.

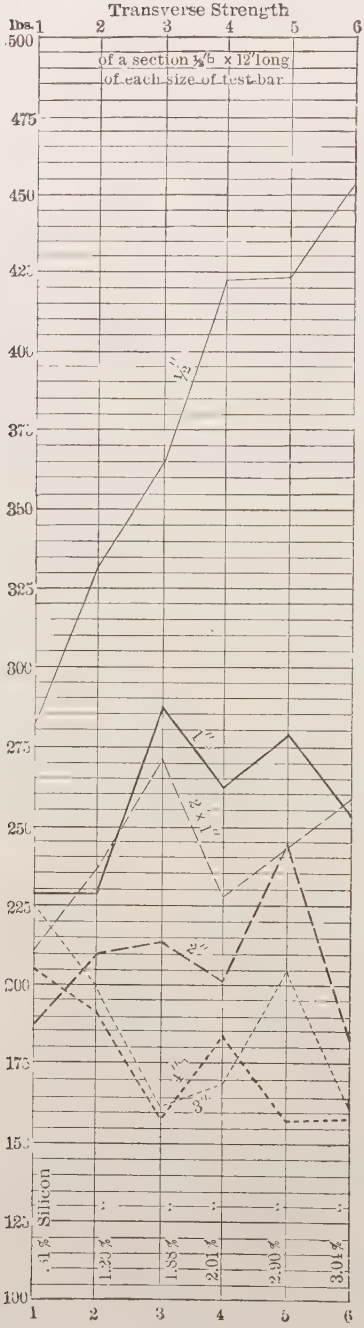

Transverse Strength
lbs.
of a section ½ x 12" long
of each size of test-bar
Silicon
.91 %
1.39 %
1.88 %
2.01 %
2.90 %
3.01 %

FIG. 2.

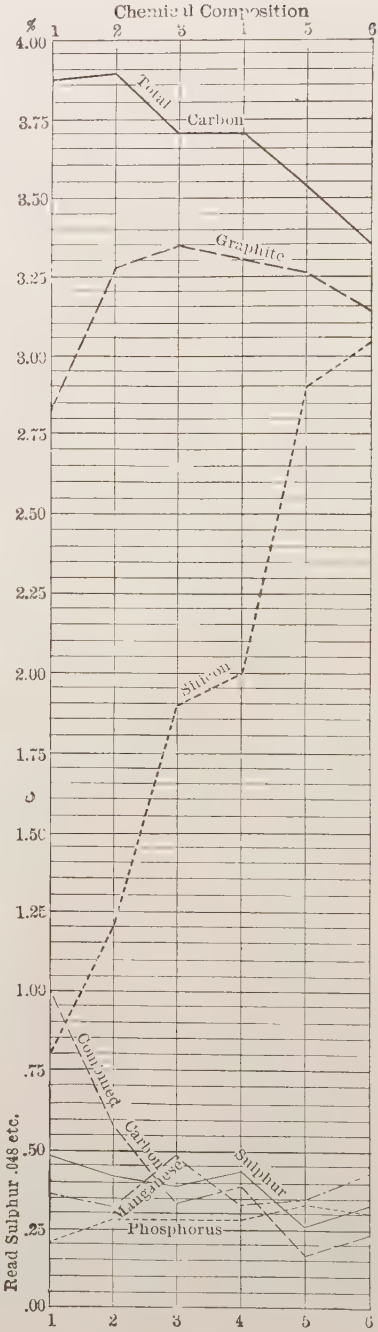

Chemical Composition
%
Total Carbon
Graphite
Silicon
Combined Carbon
Manganese
Sulphur
Phosphorus
Read Sulphur .048 etc.

FIG. 3.

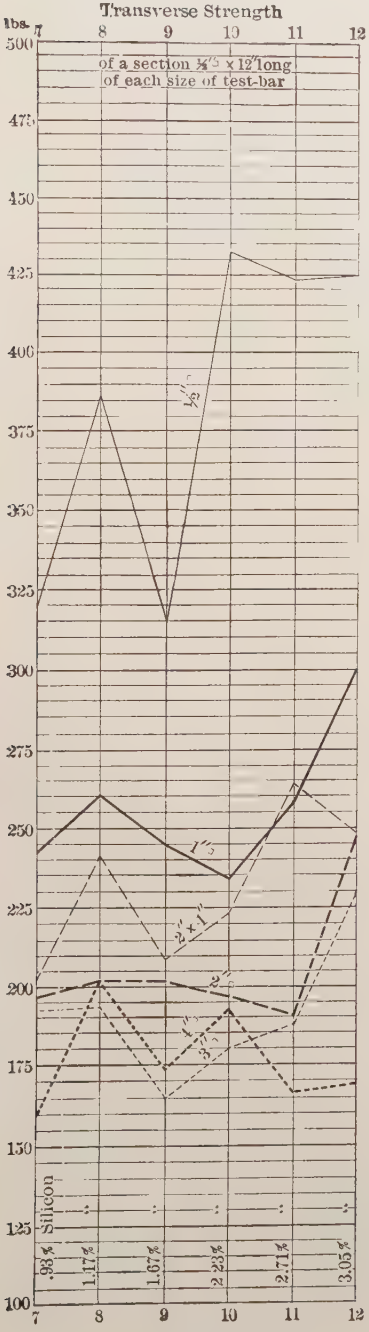

Transverse Strength
lbs.
of a section ½" x 12" long of each size of test-bar
1"
1½"
2" x 1"
2"
3"
4"
5"
Silicon
.93%
1.17%
1.67%
2.23%
2.71%
3.05%

FIG. 4.

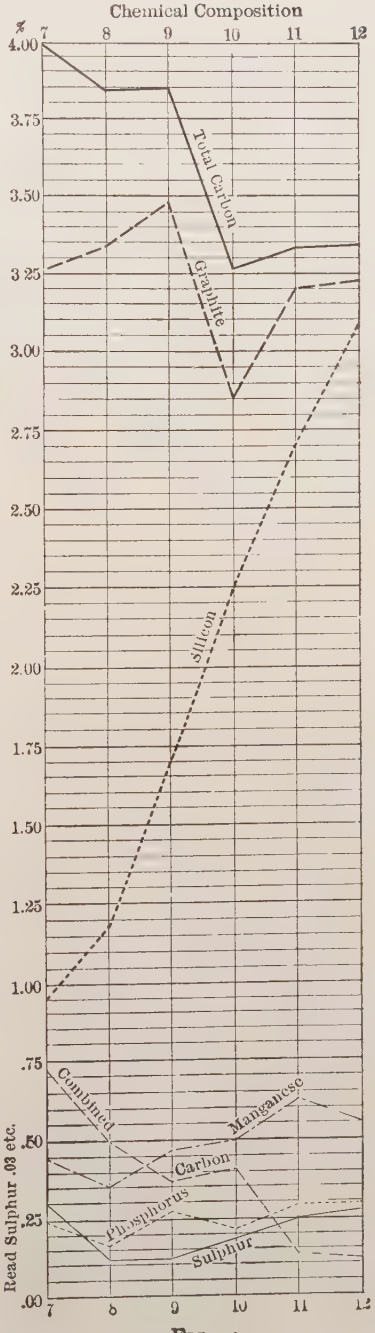

Chemical Composition
%
Total Carbon
Graphite
Silicon
Combined
Manganese
Carbon
Phosphorus
Sulphur
Read Sulphur .03 etc.

FIG. 5.

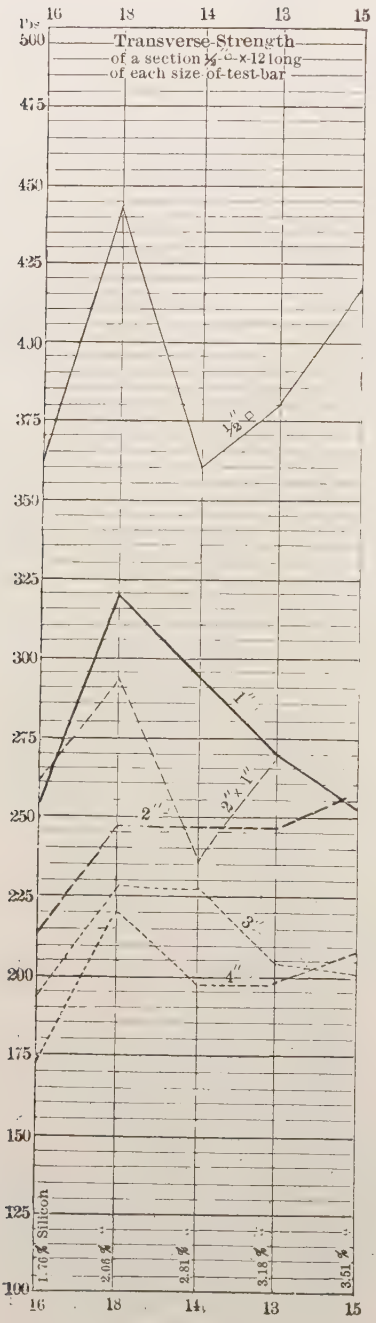

Transverse Strength
of a section ½ C. x 12 long
of each size of test bar
Lbs
500
475
450
425
400
375
350
325
300
275
250
225
200
175
150
125
100
16
18
14
13
15
½"
1"
2"
2" x 1"
3"
4"
Silicon
1.76 %
2.06 %
2.81 %
3.18 %
3.51 %

FIG. 6.

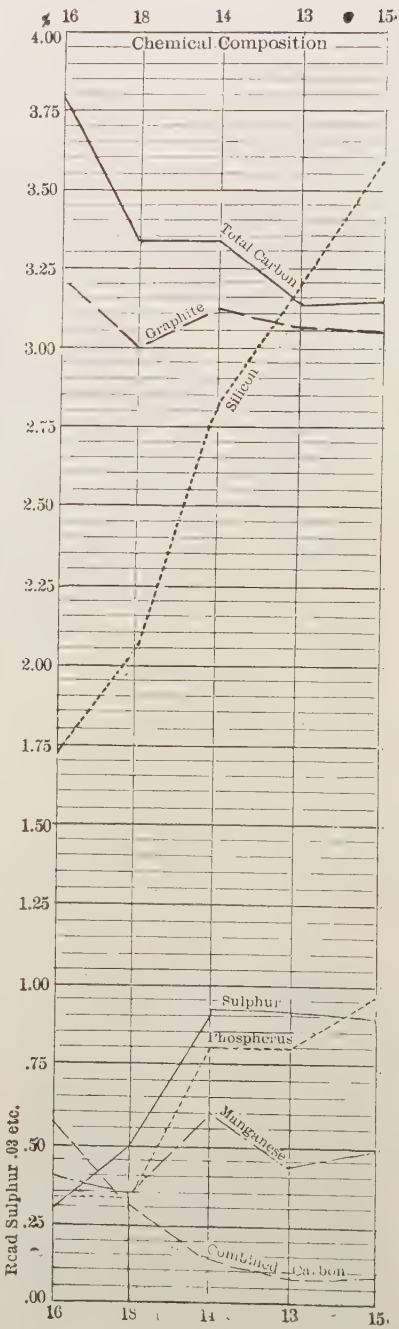

%
Chemical Composition
4.00
3.75
3.50
3.25
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
.75
.50
.25
.00
16
18
14
13
15
Total Carbon
Graphite
Silicon
Sulphur
Phosphorus
Manganese
Combined Carbon
Read Sulphur .03 etc.

FIG. 7.

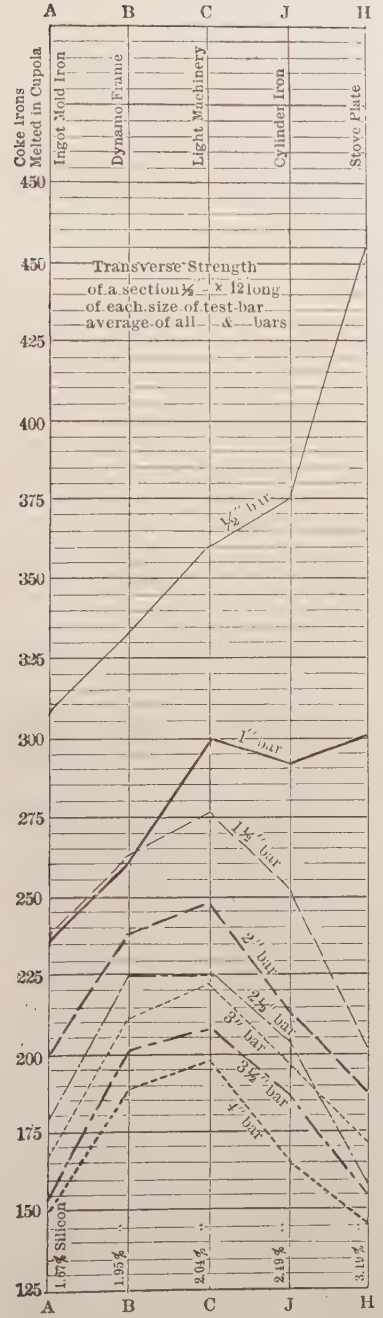

A B C J H
Coke Irons Melted in Cupola
Ingot Mold Iron
Dynamo Frame
Light Machinery
Cylinder Iron
Stove Plate
Transverse Strength of a section ½" x 12 long of each size of test-bar average of all 4 bars
½" bar
1" bar
1½" bar
2" bar
2½" bar
3" bar
3½" bar
4" bar
1.67% Silicon
1.95%
2.04%
2.19%
3.19%
450
425
400
375
350
325
300
275
250
225
200
175
150
125

FIG. 8.

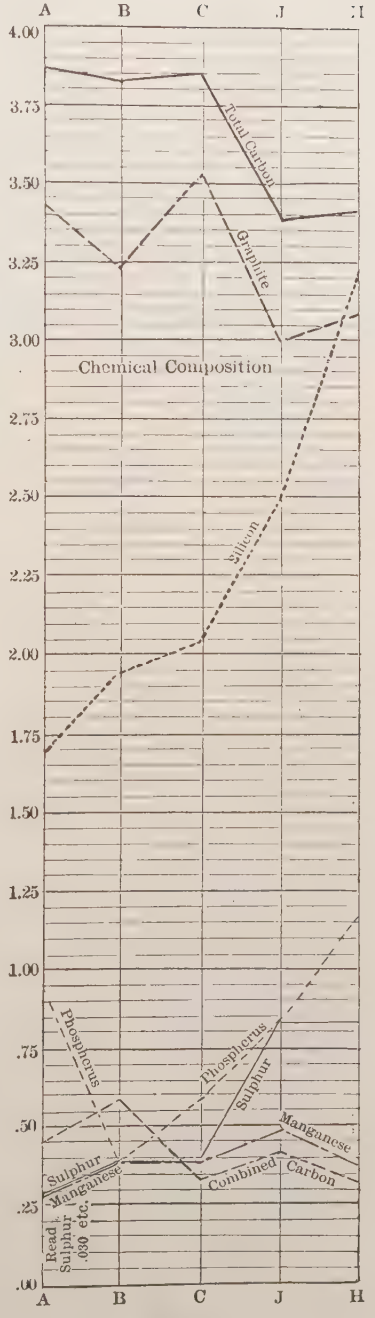

A B C J H
4.00
3.75
3.50
3.25
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
.75
.50
.25
.00
Total Carbon
Graphite
Chemical Composition
Silicon
Phosphorus
Phosphorus
Sulphur
Manganese
Sulphur
Manganese
Combined Carbon
Read Sulphur .030 etc.

FIG. 9.

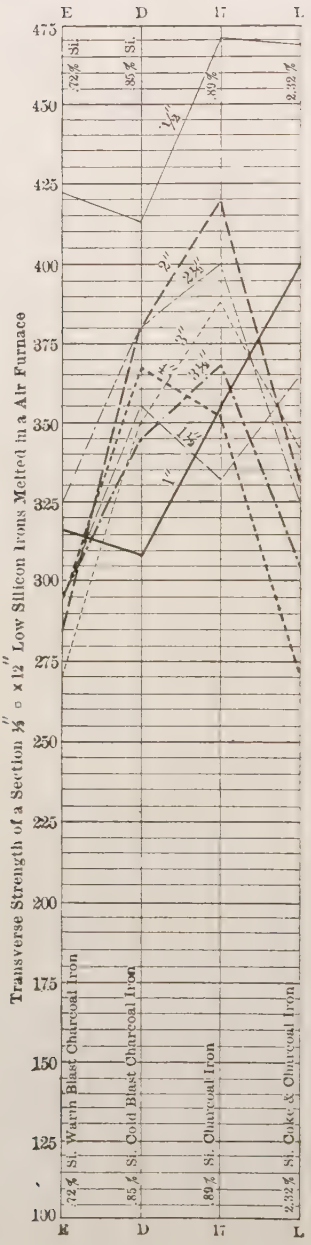


FIG. 10.

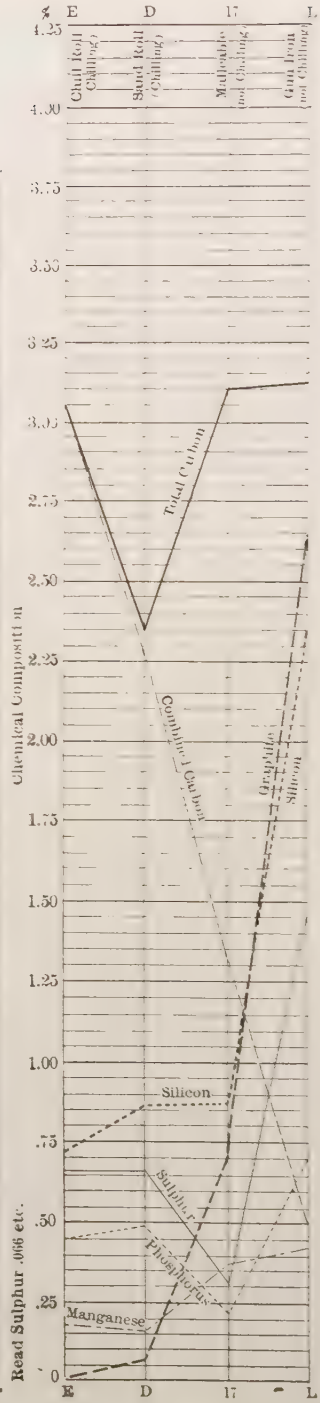


FIG. 11.

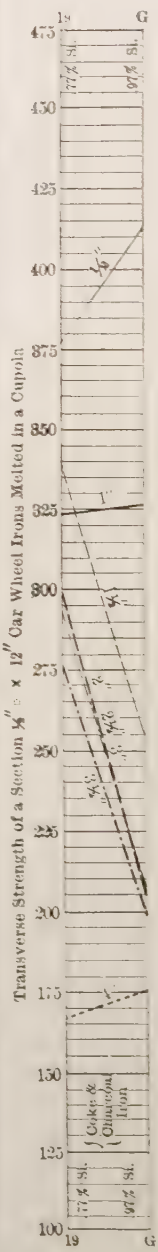


FIG. 12.

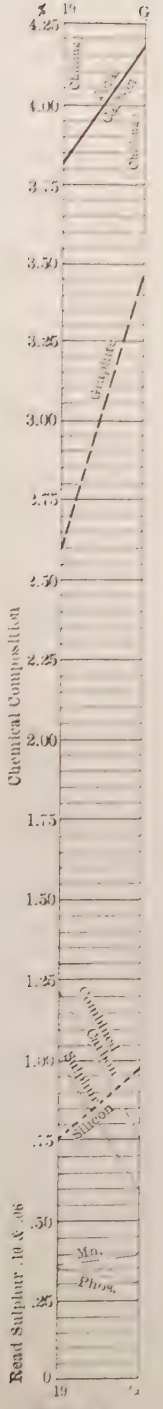


FIG. 13

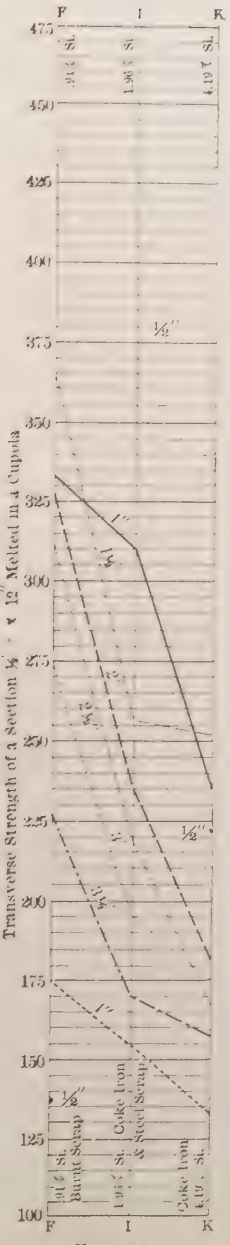


FIG. 14.

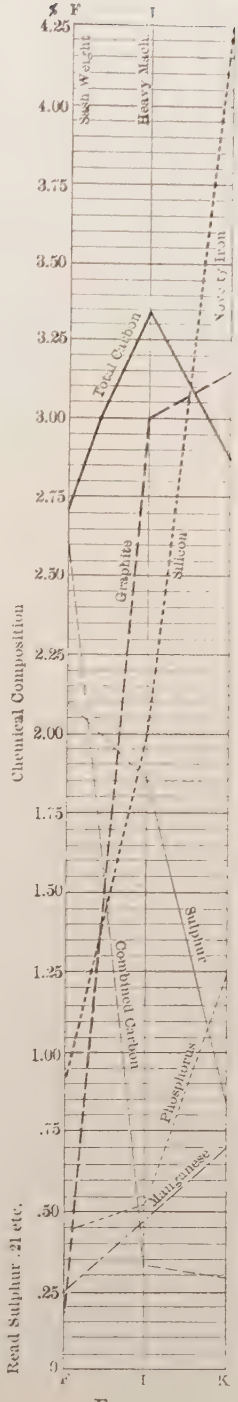


FIG 15.

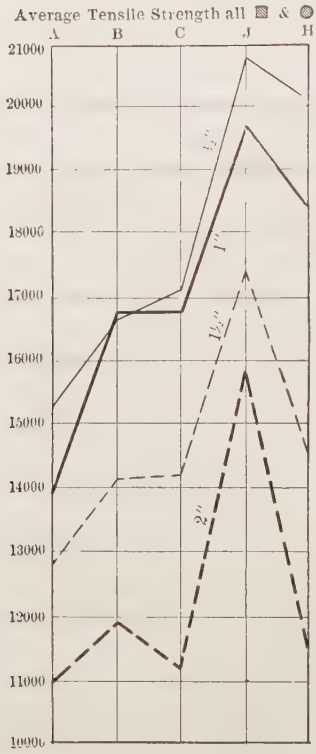


FIG. 16.

The American Society of Mechanical Engineers records are the average of two test bars of rectangular section cast together. The American Foundrymen's Association records are the average of all bars of the same area both square or round, in most cases the average of sixteen bars. These strengths and the chemical composition of these bars are shown graphically in the figures 2 to 16.

PHYSICAL AND CHEMICAL SIMILARITY.

In the preceeding figures, take the line or curve representing any chemical element and compare its variation with the variation of the line representing the strength of each size of test bar and note the apparent similarity. After completing the examination condense the results for the influence of each chemical element.

CHEMICAL COMPOSITION AND STRENGTH.—*Silicon.*—Up to

3.00 per cent silicon increases the strength of small castings, such as ½-inch test bars. Up to 2.00 per cent it increases the strength of 1-inch test bars.

In the air furnace casts *D*, *E* and *L*, ½-inch, 1-inch and 1½-inch test bars all increase in strength as silicon increases, and all other sizes increase in strength to .90 per cent silicon.

In cupola mixtures with silicon over 1.00 per cent test bars larger than 1 inch usually decrease in strength as silicon increases.

The tensile tests, Fig. 16, of all bars up to 2 inches and to 2.50 per cent show an increase in strength, but a decrease for 3.00 per cent.

Total Carbon.—In gray iron, transverse strength decreases with increase of total carbon. The tensile strength shows no such uniformity.

In Series 1, Fig. 12, steel scrap was added to decrease total carbon and to increase strength, but this was not as strong as *B*, Fig. 8, with no scrap, though both have the same silicon.

Total carbon increases as silicon decreases because silicon changes combined to graphitic carbon, and some of this escapes as the metal cools.

The increase in strength and decrease in total carbon in test bars up to 2 inches is caused by the increase of silicon which removes brittleness.

Combined Carbon.—This always decreases as silicon increases with normal conditions. The transverse strength of ½-inch and 1-inch test bars gradually increased while combined carbon decreased, but in larger bars strength and combined carbon both decreased.

This was due to the slow cooling which increased the size of the grain. The average of all tensile tests shows an increase of strength as combined carbon decreases.

If it was the decrease of combined carbon which caused the decrease in strength in large test bars the smaller bars would not show the opposite result.

Analysis of each size of test bar often shows the same combined carbon in small and in large bars, but the small bars are invariably strong and the large bars weak due to slow cooling.

In Fig. 9, *B* has the lowest combined carbon and the greatest

strength of the group. In *J* the strength drops in all sizes of test bars while combined carbon is slightly greater.

Comparing *B* with *I* (Fig. 13), while both have the same silicon, *I* has very much lower combined carbon and is very much stronger in the $\frac{1}{2}$-inch and 1-inch bars; is about the same strength in the $1\frac{1}{2}$-inch, 2-inch and $2\frac{1}{2}$-inch bars, but the 3-inch, $3\frac{1}{2}$-inch and 4-inch bars are much weaker. (Steel scrap added to *I* did not act as expected.)

Closing the grain and removing brittleness increases strength. Melting in an air furnace, Fig. 14, increases both strength and combined carbon.

Graphitic Carbon.—The quantity in any casting is the difference between the total and the combined carbon. In these series there is no uniformity between the percentage of graphite and the strength.

Phosphorus.—In all of these series phosphorus generally increases as silicon increases.

While the tensile tests, Fig. 16, show an increase of strength with an increase of phosphorus, yet the transverse tests, especially Figs. 6 to 9, seem to show that phosphorus reduces strength. This is also general shop experience.

Sulphur.—There is not in these tests enough uniformity between the percentage of sulphur and the strength to show any decided influence, but the indication is that sulphur decreases strength. In some cases sulphur might add to strength by causing the grain to be closer.

Manganese.—The percentage is too nearly the same in these series to show any influence on strength.

By comparing strengths and chemical composition of the irons nearest alike, as 3, 9, 16, *A*, or 5, 18, *B*, *C*, *I*, or 13, *H*, or 6, 12, with all chemical elements nearly alike, and no scrap, but with quite different strengths, it is very evident that strength is dependent upon something outside of the ordinary chemical composition.

Slow Cooling Decreases Strength by making the grain of a casting coarse and more open. The larger the casting the weaker it becomes per square inch of section. The weakness is not caused by a decrease in combined carbon because a complete analysis of each size of test bar (*Transactions*, American Society of Mechanical Engineers, Volume XVI, p. 1100) shows the same combined carbon

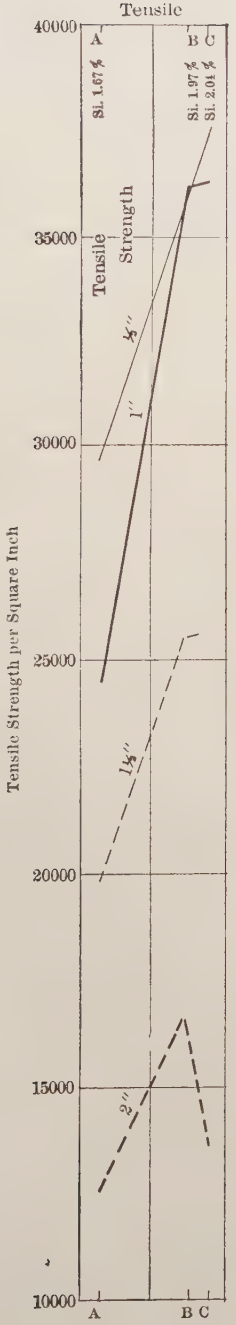


FIG. 17.

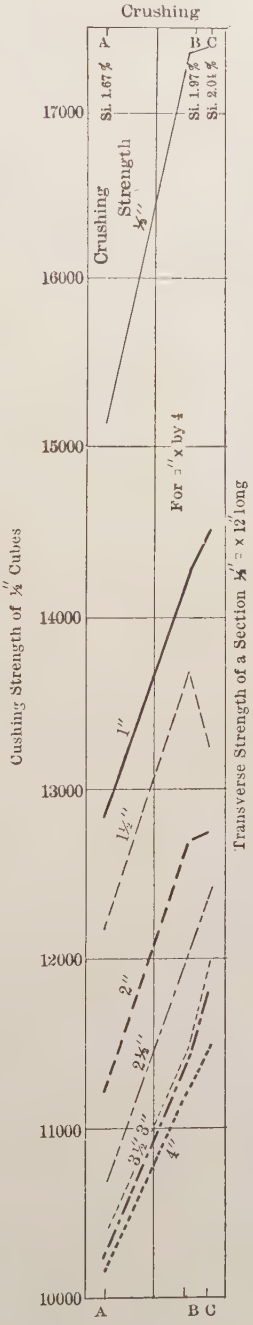


FIG. 18.

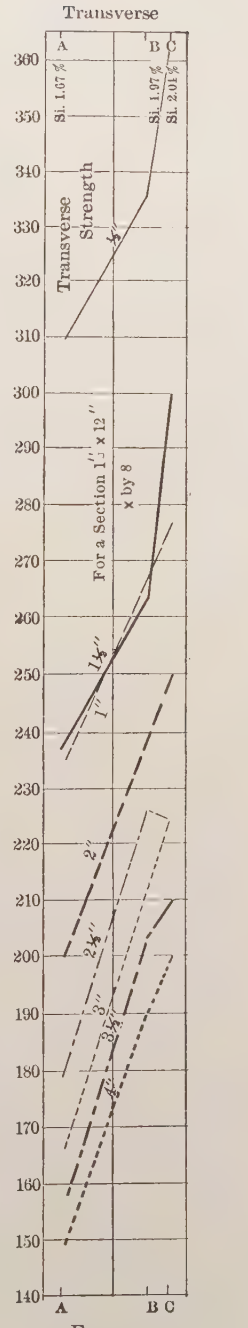


FIG. 19.

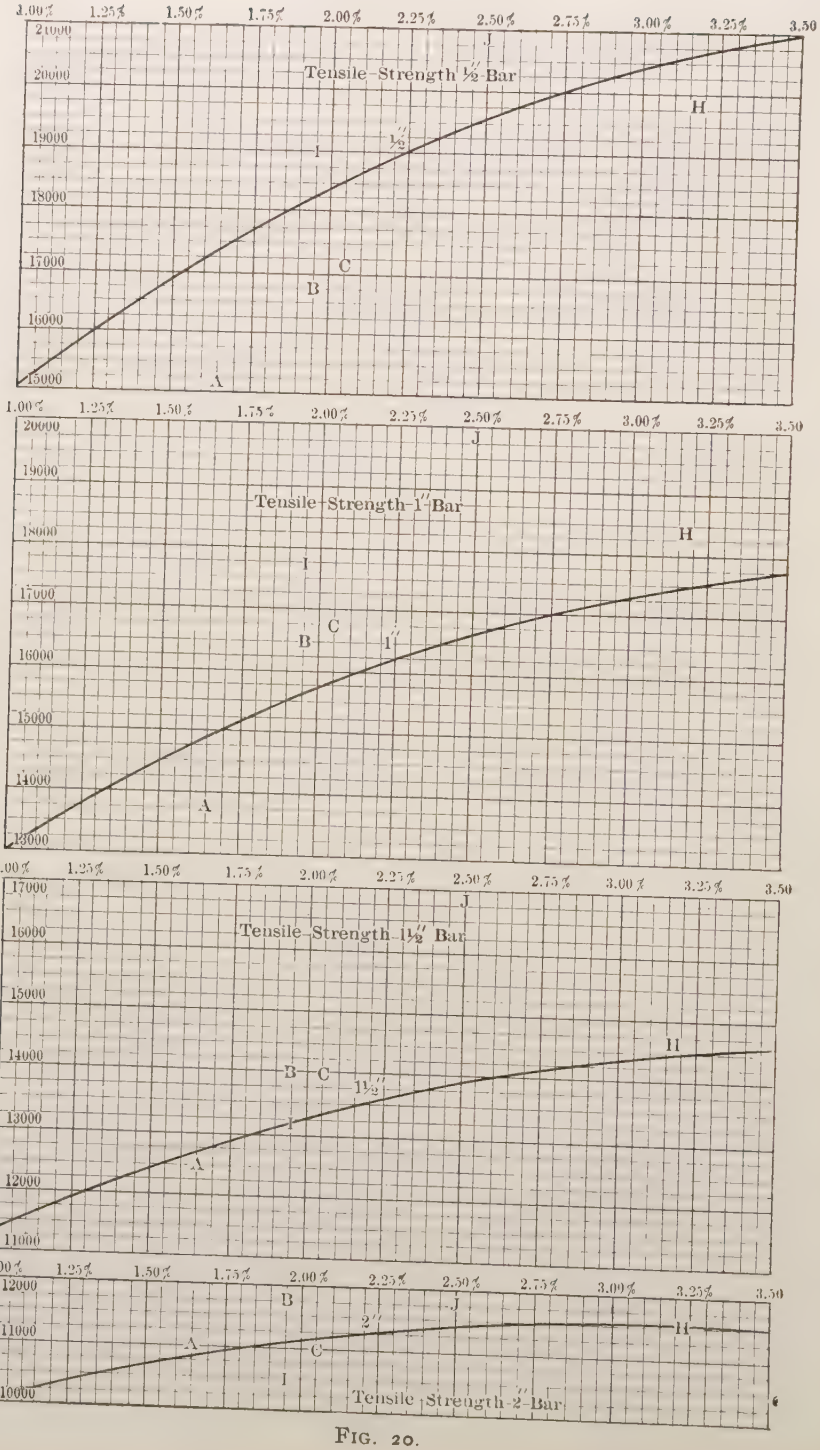
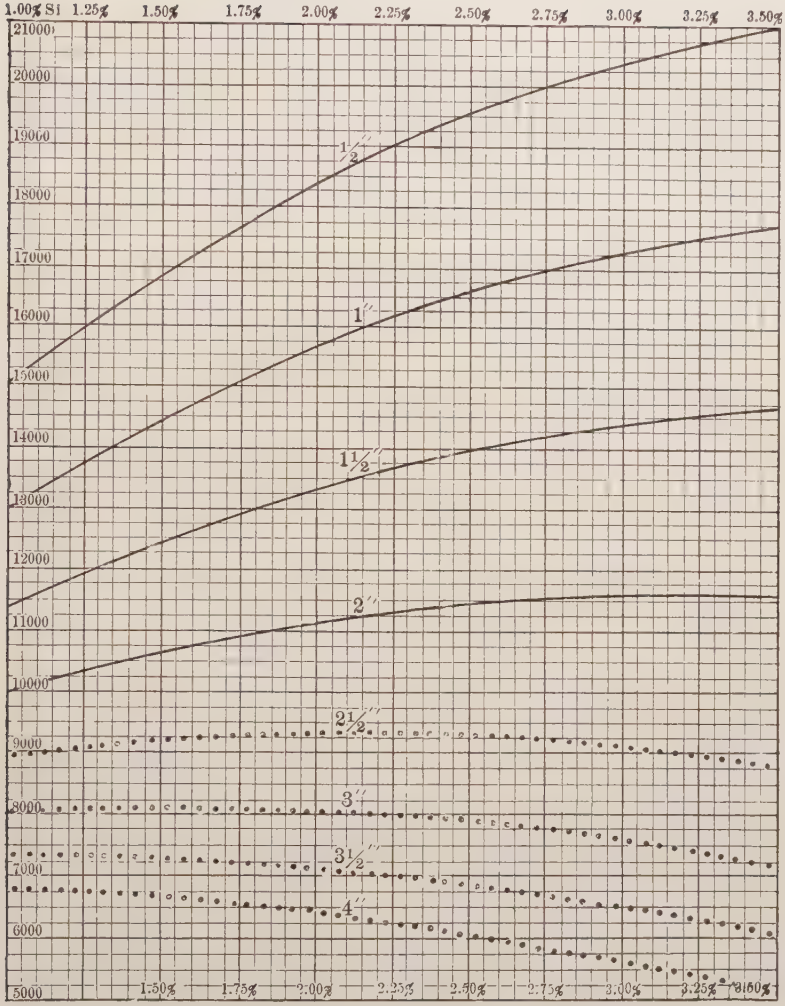

1.00% 1.25% 1.50% 1.75% 2.00% 2.25% 2.50% 2.75% 3.00% 3.25% 3.50
20000
19000
18000
17000
16000
15000
Tensile Strength ½" Bar
J
H
I
½"
C
B
A
1.00% 1.25% 1.50% 1.75% 2.00% 2.25% 2.50% 2.75% 3.00% 3.25% 3.50
20000
19000
18000
17000
16000
15000
14000
13000
Tensile Strength 1" Bar
J
H
I
C
B
1"
A
1.00% 1.25% 1.50% 1.75% 2.00% 2.25% 2.50% 2.75% 3.00% 3.25% 3.50
17000
16000
15000
14000
13000
12000
11000
Tensile Strength 1½" Bar
J
H
B
C
1½"
I
A
1.00% 1.25% 1.50% 1.75% 2.00% 2.25% 2.50% 2.75% 3.00% 3.25% 3.50
12000
11000
10000
B
J
2"
H
A
C
I
Tensile Strength 2" Bar

FIG. 20.



KEEP'S TENSILE STRENGTH CHART.

Approximate relation of strength to size of casting and to percentage of silicon. (Table gives the strength per square inch.)

FIG. 21.

in all sizes of many series, but in all cases the strength per unit of section decreased as the size increased.

Strength of Any Size of Test Bar cannot be Calculated by Any Mathematical Formula from the Measured Strength of Another Size, because the grain changes by slow cooling. Such strength must

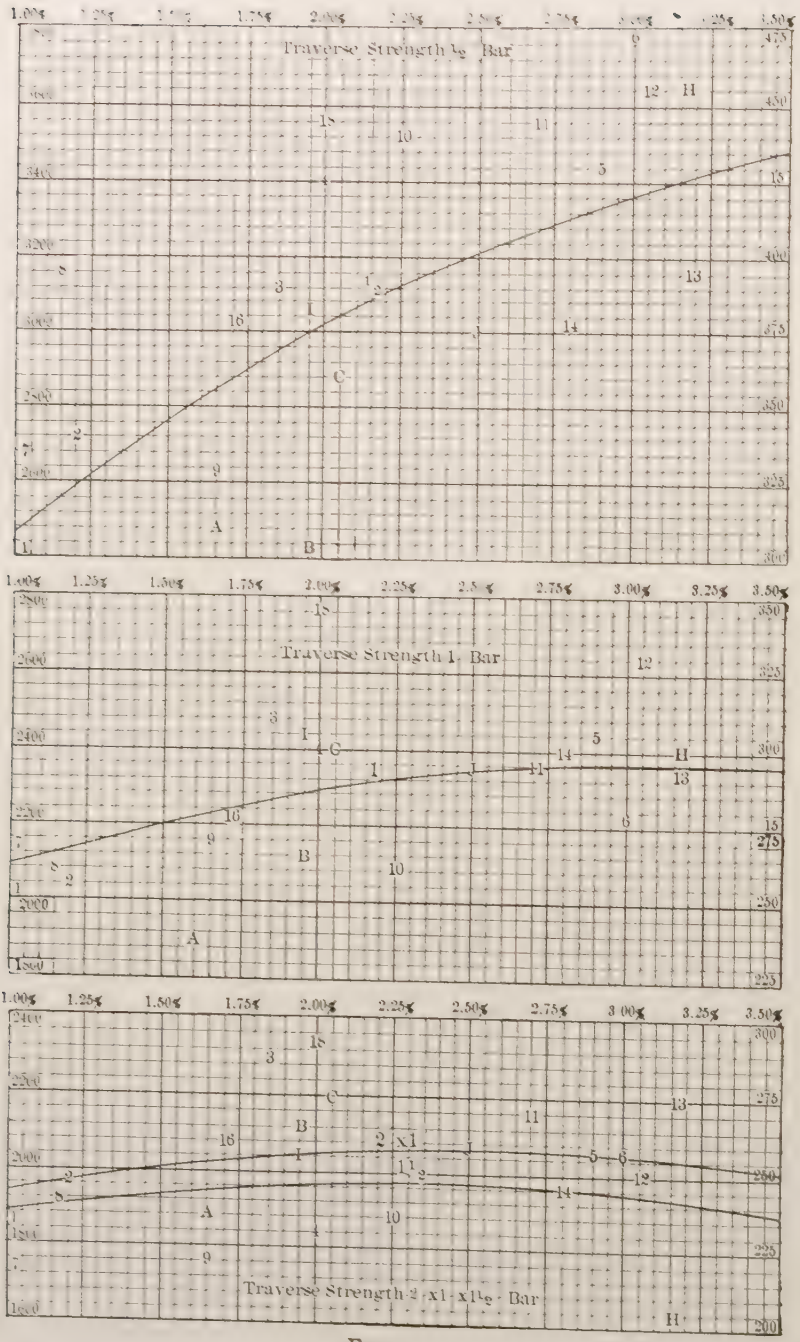
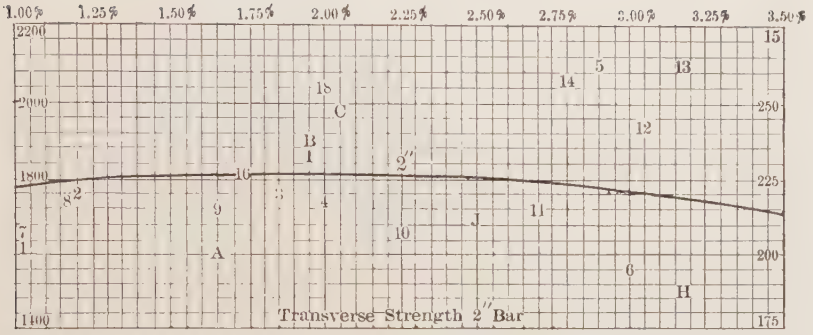
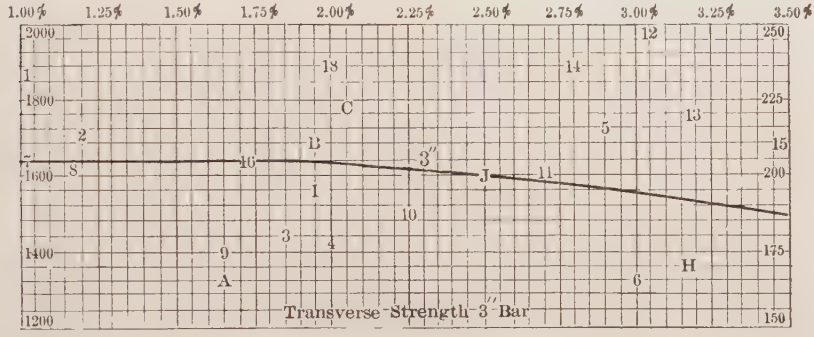

Traverse Strength 1/8 Bar
Traverse Strength 1 Bar
Traverse Strength 2 x1 x1 1/8 Bar

FIG. 22.





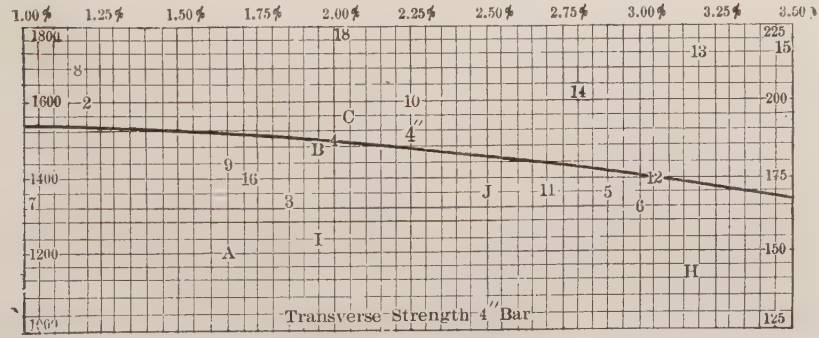
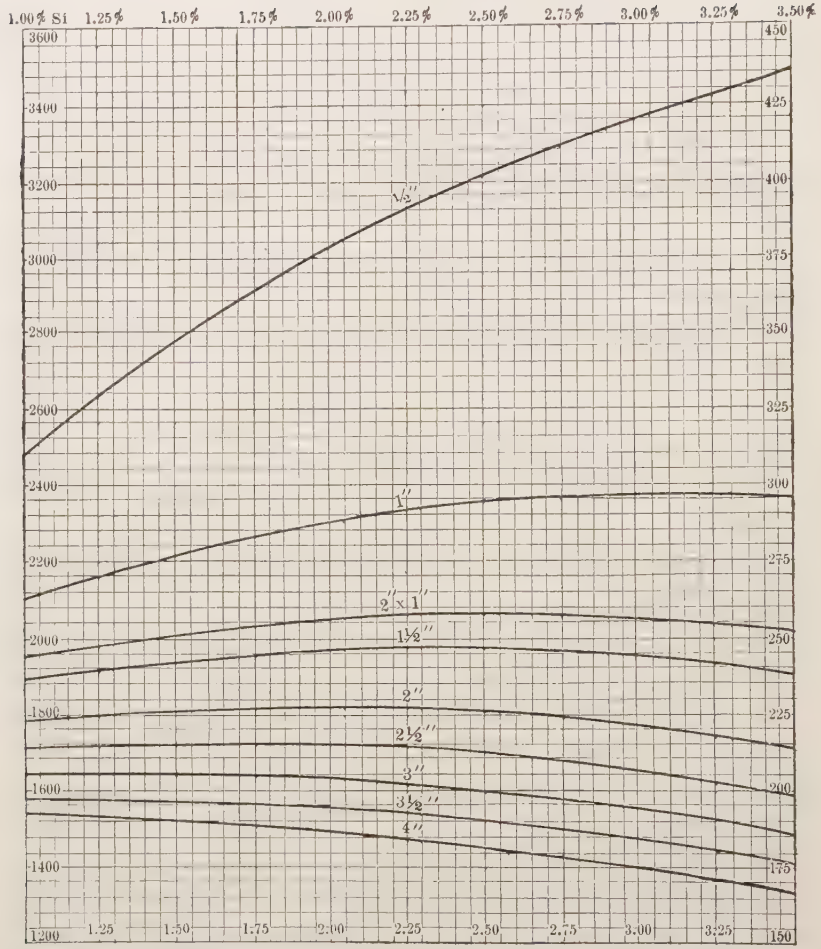


FIG. 22—Continued.



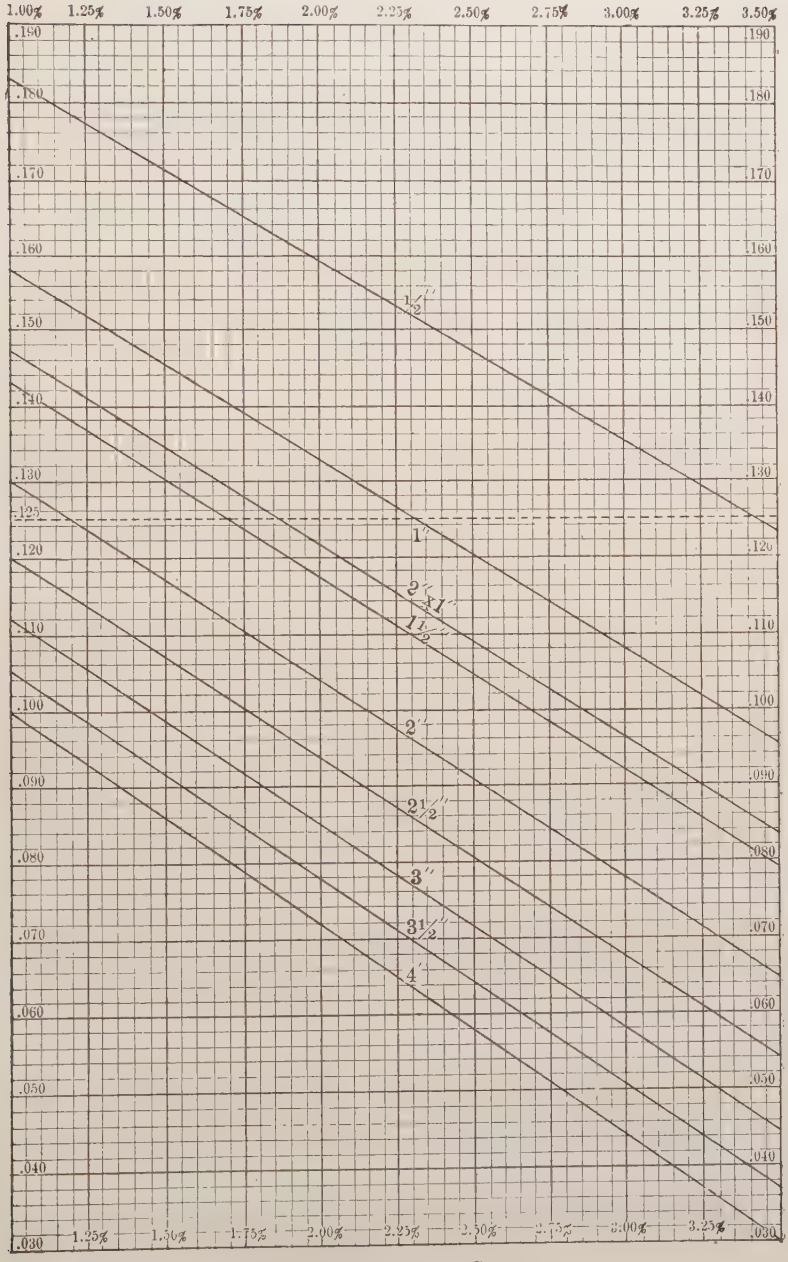
KEEP'S TRANSVERSE STRENGTH CHART.

Approximate relation of strength to size of casting and to percentage of silicon. (Table gives strength of a section of each test bar 1" square x 12" long.)

FIG. 23.

be obtained by a graphic chart. Fig. 17 shows the average tensile strength per square inch, Fig. 18 the average crushing strength of a ½-inch cube, and Fig. 19 the average transverse strength of a section 1 inch square by 12 inches, of each size of test bar of series *A*, *B* and *C*.

The similarity in the diagrams of each of these three kinds of



KEEP'S SHRINKAGE CHART.

Approximate relation of shrinkage to size of casting and to percentage of silicon.

FIG. 24.

strengths shows that a graphic chart should show this general character of diagram. Fig. 20 shows the average tensile strength of each size of test bar of each of the American Foundrymen's Association tests and also gives a line showing the average tensile strength.

TABLE I.

KEEP'S TABLE FOR APPROXIMATE TRANSVERSE STRENGTH.

Per cent of Silicon ..	1.00%	1.25%	1.50%	1.75%	2.00%	2.25%	2.50%	2.75%	3.00%	3.25%	3.50%
SIZE OF TEST BAR:											
½ in. sq....	1.179	1.246	1.253	1.287	1.318	1.346	1.370	1.394	1.418	1.443	1.471
	.1473	.1558	.1567	.1610	.1648	.1683	.1713	.1743	.1772	.1804	.1839
1 in. sq.....	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.
2 x 1 in....	.9286	.9188	.9995	.8982	.8932	.8860	.8787	.8750	.8587	.8586	.8520
	1.857	1.838	1.819	1.796	1.787	1.772	1.757	1.750	1.717	1.717	1.704
1½ in. sq...	.8976	.8863	.8733	.8629	.8562	.8473	.8383	.8326	.8228	.8122	.8055
	3.029	2.991	2.947	2.912	2.890	2.860	2.829	2.810	2.777	2.741	3.141
2 in. sq....	.8429	.8306	.8167	.8009	.7908	.7806	.7681	.7585	.7447	.7342	.7225
	6.743	6.645	6.534	6.407	6.327	6.245	6.145	6.068	5.958	5.873	5.780
2½ in. sq...	.8117	.7935	.7783	.7611	.7473	.7365	.7213	.7098	.6962	.6857	.6701
	12.68	12.40	12.16	11.89	11.68	11.49	11.27	11.09	10.88	10.71	10.47
3 in. sq....	.7833	.7610	.7421	.7235	.7102	.6968	.6808	.6695	.6540	.6413	.6300
	21.64	20.55	20.04	19.53	19.18	18.81	18.38	18.08	17.66	17.32	17.01
3½ in. sq...	.7524	.7309	.7104	.6925	.6776	.6624	.6468	.6356	.6224	.6097	.5962
	32.26	31.34	30.46	29.69	29.05	28.40	27.73	27.25	26.68	25.84	25.56
4 in. sq....	.7654	.7100	.6900	.6681	.6493	.6344	.6191	.6059	.5907	.5781	.5646
	46.78	45.44	44.16	42.76	41.55	40.60	39.63	38.78	37.81	36.99	36.10

TENSILE STRENGTH CHART.—Fig. 21 shows this chart. The dotted lines are estimated.

TRANSVERSE STRENGTH CHART.—Fig. 22 and Fig. 22 (cont'd) show the average transverse strengths of each American Society

of Mechanical Engineers and American Foundrymen's Association tests and a curve showing the average strength of each size of test bar for each variation in silicon. Fig. 23 shows these curves.

SHRINKAGE CHART for approximating the percentage of silicon in any test bar or casting, Fig. 24 is constructed from the carefully measured shrinkage and analyses of each size of test bar of the American Society of Mechanical Engineers series.

Table for Obtaining the Strength of Any Size of Test Bar from the Measured Strength of a Standard Test Bar.—Table I is calculated from chart, Fig. 23, for a standard 1-inch square test bar. Measure the shrinkage per foot of the standard test bar, then on the shrinkage chart, Fig. 24, find this shrinkage on the left-hand margin and follow horizontally until you intersect the line of the measured test bar. Follow the vertical line at the

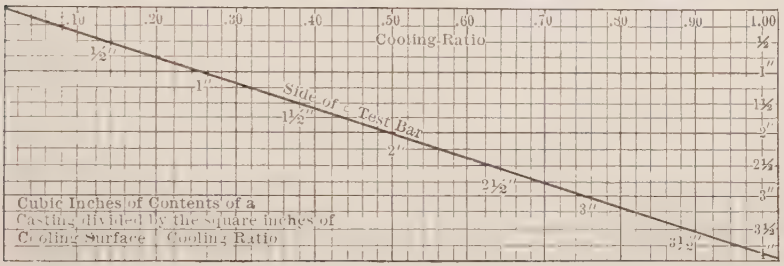


FIG. 25.

intersection to the top of the chart, and you find the percentage of silicon that is expected to produce that shrinkage. Find this same percentage at the top of Table I, and follow down to the size of test bar that you wish the strength of. If you wish the actual strength use the lower figures as a multiplier of the measured strength of the standard 1-inch bar. If you wish the strength of a section 1 inch square by 12 inches long of the required test bar use the upper number to multiply by.

If you have the strength of any size of test bar other than a 1-inch bar, and know the silicon percentage, divide such strength by the lower number for the bar, or if you have the strength of a section of the required test bar 1 inch square by 12 inches long, divide by the upper number, and the result in either case is the strength of the standard 1-inch bar.

To Find the Strength of Any Casting.—Divide the cubic con-

tents of a casting by the square inches of cooling surface, and the quotient is the cooling ratio. If the casting has a large flat surface the edges may be neglected; for example, a casting 1 inch thick and 24 inches square. A strip 1 inch wide and 24 inches long would have 24 cubic inches contents and 48 square inches of cooling surface. $24 \div 48 = .5$ ratio. Find this ratio at the top of the chart, Fig. 25, and follow down to the diagonal, and we find that a 2-inch square test bar represents the strength of the casting.

With the shrinkage of a standard 1-inch test bar, cast at the same time as the casting, find on the shrinkage chart the percentage of silicon in the casting, then in Table I find the upper multiplier for a 2-inch test bar. This multiplied by the measured strength of the standard test bar gives the strength of a section of the casting 1 inch square and 12 inches long.

PROPOSED SPECIFICATIONS FOR CAST IRON.

At the appointment of a committee by the International Association for Testing Materials at Zurich in 1895, the charge was: "On the basis of existing specifications to seek methods and means for the introduction of international specifications for testing and inspecting iron and steel of all kinds." (W. R. Webster and Edgar Marburg at Atlantic City meeting of American Institute of Mining Engineers, February, 1904, paper, "The Standardization of Specifications," etc.) The secretary of the American section of the Committee on Cast Iron says that the "committees began to collect information on existing methods and to formulate specifications based thereon as far as possible, the final results being intended to represent the best American practice at the present time." (Richard Moldenke at above meeting, paper, "Specifications for Cast Iron," etc.)

The following are submitted as desirable by the various committees:

GENERAL GRAY IRON CASTINGS AND METHOD OF TESTING.—*Chemical Properties.*

Light castings	sulphur not over	0.08 per cent.
Medium "	" "	0.10 " "
Heavy "	" "	0.12 " "

Definition.—Light castings are those less than $\frac{1}{2}$ inch thick. Heavy castings more than 2 inches thick. Medium all between.

Physical Properties. Transverse Test.—The minimum breaking strength of the "Arbitration Bar" ($1\frac{1}{4}$ inches diameter) under transverse load shall not be under

Light castings	25,000 lbs.
Medium "	2,900 "
Heavy "	3,300 "

In no case shall the deflection be under .10 of an inch.

Tensile Test not less than

Light castings	18,000 lbs. per sq. in.
Medium "	21,000 " " " "
Heavy "	24,000 " " " "

Two sets of round bars $1\frac{1}{4}$ inches diameter shall be cast from each heat, one set from the first and the other set from the last iron going into the castings. The transverse test shall be made on all the bars cast with supports 12 inches apart, load applied at the middle. One bar of every two of each set made must meet requirements.

AMERICAN FOUNDRYMEN'S ASSOCIATION specification. Light and medium weight castings silicon 1.75 per cent and up, test bars $1\frac{1}{2}$ inches diameter.

Heavy castings silicon 1.50 to 2.00 per cent, test bars 2 inches diameter.

Chilling irons silicon below 1.00 per cent, test bar $2\frac{1}{2}$ inches diameter.

No specification for strength.

PIPE CASTINGS, no chemical specification given.

Physical Test.—Test bar 2 inches wide, 1 inch deep, supports 24 inches apart and loaded at center. For pipe 12 inches diameter and less, breaking load 1,900 pounds with not less than 30-inch deflection.

For pipe larger than 12 inches, load 2,000 pounds with deflection not less than .32 inch. The test shall be based upon the average result of three test bars.

LOCOMOTIVE CYLINDERS.—*Chemical Properties.*

Silicon	from 1.25 to 1.75 per cent.
Phosphorus	not over .90 per cent.
Sulphur	" " .10 " "

Physical Properties.—"Arbitration test bar," $1\frac{1}{4}$ inches diameter, supports 12 inches apart, strength not less than 2,700

pounds, deflection not less than .08 inch. One test bar for each cylinder. Acceptance or rejection in case of dispute based on chemical analysis.

MALLEABLE CASTINGS.—*Chemical Properties.*—Sulphur not over .06, phosphorus not over .225.

Physical Properties.—Standard test bar 1 inch square, supports 12 inches apart, transverse strength after annealing not less than 3,000 pounds, deflection at least ½ inch. Tensile strength, the same size of bar, not less than 42,000 pounds per square inch.

"EXISTING METHODS" AND SPECIFICATIONS.

The reply to letters to leading founders and chemists was generally that they used no specifications.

THE UNITED ENGINEERING AND FOUNDRY COMPANY, comprising many of the largest foundries in the Pittsburg district, says: "We watch our silicons and sulphurs pretty carefully for the ordinary run of castings, and when we desire castings of high strength we make a mixture from scrap and pig that, when melted in an air furnace, will give us a silicon of about 1.50 per cent."

PHILADELPHIA AND READING RAILWAY COMPANY.—"With 50 per cent of pig iron as per specification and 50 per cent of good scrap with ferro manganese in the ladle, we got a very tough, close-grained iron which turns up almost like steel. We get the best results by the combination of analysis from the castings themselves combined with the appearance and character of the fracture, and we avoid test bars owing to the difficulty of having them represent the general condition of the castings. We used a test bar 1.13 inches diameter, 12 inches between supports. Our former specifications were roughly:

Medium Iron, engine cylinders, gears, etc. Silicon 1.40 to 2.00 per cent. Sulphur less than .085 per cent. Phosphorus less than .60 per cent. Manganese less than .70 per cent. Transverse strength about 2,400 pounds per square inch."

"*Soft Iron*, general car and railway use. Silicon 2.00 to 2.80 per cent. Other elements same as medium iron. Transverse strength 2,000 pounds."

"*For Brake-shoes* and other castings for frictional wear. Silicon 2.00 to 2.50 per cent. Sulphur less than .15 per cent. Phosphorus less than 0.70 per cent. Manganese less than 0.70 per cent. Transverse strength 2,900 pounds."

J. I. CASE THRESHING MACHINE COMPANY SPECIFICATIONS and used by a large number of Western founders, and published by their chemist, Mr. W. G. Scott, are as follows:

Close Hard Iron for air and ammonia compressors, H. P. cylinders, H. P. valves, etc. Silicon 1.20 to 1.60 per cent (below too hard, above porous, unless much scrap is used). Sulphur less than .095 per cent. Phosphorus below 0.70 per cent (for chill .30 per cent). Manganese below .70 per cent (higher for chill). Transverse strength, test bar 1 inch square by 12 inches cast in yokes, 2,400 pounds. Tensile strength per square inch 22,000. Shrinkage (bar 1 inch square by 12 inches), not more than .161 inch. Chill in yokes below .25 inch.

Medium Iron for engine cylinders, gears, pinions, etc. Silicon 1.40 to 2.00 per cent (1.50 best for gears). Sulphur less than .085 per cent (best .075 to .080). Phosphorus below .70 per cent. Manganese below .70 per cent. Transverse strength 2,200, tensile 2,000. Shrinkage not more than .154 inch, chill .15 inch.

Soft Iron for pulleys, small castings and agricultural work. Silicon 2.20 to 2.80 per cent (below too hard, above weak for large castings, 2.40 a good average). Sulphur less than .085. Phosphorus below .70 (1.00 for stove plate). Manganese below .70 per cent. Transverse strength 2,000. Tensile 18,000. Shrinkage .141 inch. Chill .05 inch.

THE LORAIN FOUNDRY COMPANY.—Mr. Oliver Phelps, former general manager, gave me the following: "The efforts of the Lorain foundry were devoted specially to large and heavy castings. Size of test bar 2 inches wide, 1 inch deep and 24 inches between supports. Three test bars.

Hard Iron, for compressor cylinders, valves and high-pressure work. Silicon 1.20 to 1.50 per cent. Sulphur under .09. Phosphorus .35 to .60. Manganese .50 to .80. Transverse strength 2,600 pounds per square inch. Tensile 24,000 pounds per square inch.

Medium Iron for general work. Silicon 1.50 to 2.00 per cent. Sulphur under .08 per cent. Phosphorus .35 to .60. Manganese .50 to .80. Transverse strength 2,400 pounds per square inch. Tensile 23,000. The above are cupola melts with best Connellsville coke. Limestone flux.

In some cases for density we place in the ladle ½ to 1 per cent

of aluminum. For castings of over 15 tons we sometimes mixed air furnace and cupola iron, gaining nearly 30 per cent increase in strength in both tests. I think our high tests were, however,

TABLE II.

			Silicon.	Sul.	Phos.	Mn.	Transverse.	Tensile.	Shrink.	Chill.
Furnace.	Heavy	U. S. Eng. & Fd'y Co.	1.50%							
		Lorain Fd'y Co.	1.20 to 1.40	.085	.24	.37	3,900	37,962		
	Medium	Am. Fd'y Ass'n	2.35	.044	.676	.43	3,200	29,000		
Cupola.	Heavy	Lorain Fd'y Co.	1.20 to 1.50	.09	.35–.60	.50–.80	2,600	24,000		
	Medium	Lorain Fd'y Co.	1.50 to 2.00	.08	.35–.60	.50–.80	2,400	23,000		
	Heavy	A. S. for T. M.		.12			2,533	24,000		
		Am. Fd'y Ass'n	1.50 to 2.00							
		Loco-Cyl	1.25 to 1.75	.10	.90		2,070			
		J. I. Case T. M. Co.	1.20 to 1.60	.095	.70	.70	2,400	22,000	.161″	.25″
	Medium	A. S. for T. M.		.10			2,232	21,000		
		Am. Fd'y Ass'n	1.75 up							
		Pipe					2,227			
		J. I. Case T. M. Co.	1.40 to 2.00	.085	.70	.70	2,200	20,000	.154″	.15″
		Phil. & Read. Ry.	1.40 to 2.00	.085	.60	.70	2,400			
	Light	A. S. for T. M.		.08			1,936	18,000		
		Am. Fd'y Ass'n	Above 1.75							
		Pipe					2,089			
		J. I. Case T. M. Co.	2.20 to 2.80	.085	.70	.70	2,000	18,000	.141″	.05″
		Phil. & Read. Ry.	2.00 to 2.80	.085	.60	.70	2,000			
	Chemical Work L. F. Co.		1.10 to 1.35	.07	.25	.40–.60				
	Brake Shoes P. & R. Ry.		2.00 to 2.50	.15	.70	.70	2,900			
Chilling Iron A. F. A.			Below 1.00							

In Table II all of the above proposed and existing specifications are tabulated and reduced to terms of a test-bar 1 inch square x 12 inches between supports. Tensile tests are per square inch, but as the size cast is not recorded, possibly these values should be modified.

largely due to Northern lake ore irons, not over 15 per cent of our mixture being made with Southern iron.

Chemical Work Castings (cupola). Silicon 1.10 to 1.35. Sulphur under .07. Phosphorus under .25. Manganese .40 to .60 per cent.

Air Furnace Iron.—For Omaha and Pittsburg pumps 15 to 20 millions capacity, the average thickness of metal $2\frac{1}{4}$ inches, the several pieces weighing 12,000 to 29,000 pounds each. The analyses was T. C. 3.20, G. C. 2.19, C. C. 1.01, Si. 1.30, P. 0.624. S. 0.085, Mn 0.37.

This iron was melted in an air furnace with gas coke running

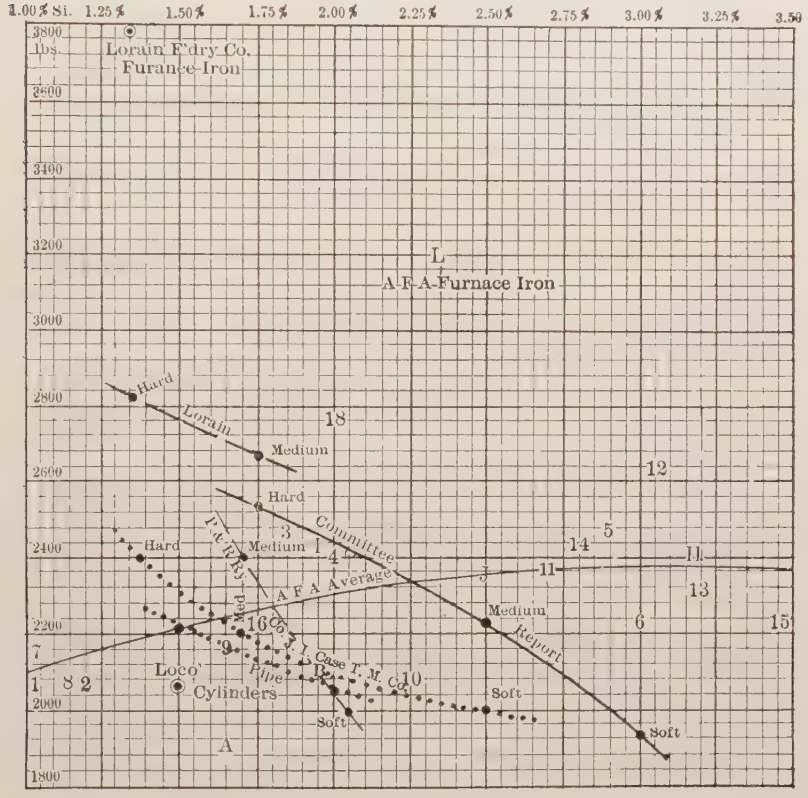


FIG. 26.

about 1.50 per cent sulphur, about 1 pound coal to 3 pounds iron. Time of heat about seven hours."

ENGLISH PRACTICE.—Professor Thomas Turner says: "For transverse test the common test adopted by iron founders is breaking a bar 3 feet long by 2 inches deep and 1 inch broad. However, many shapes and sizes of test bar have been adopted, and for scien-

tific purposes the results so obtained are converted by calculation into values for a bar one foot long and one inch square."

Fig. 26 (*see preceding page*) is a graphic chart of all of the preceding specifications reduced to terms of a bar 1 inch square by 12 inches long. There are four sizes of test bars, viz:

COMMENTS ON SPECIFICATIONS.

CHEMICAL SPECIFICATION.—The chemical properties for each kind of casting should be specified. A small variation in silicon will make castings either too hard or too porous. The general founder should be instructed on these questions. The sulphurs of the Committee for general gray iron casting are too high. The practice of the J. I. Case T. M. Company and Lorain Foundry Company should be followed closely.

A chemical specification is of the utmost importance. The Lorain air furnace iron has silicon 1.30 per cent, the grain is close and strength of a 1 inch square bar is 3,900. The American Foundrymen's Association (cast *L*) furnace iron has silicon 2.35 per cent, which would make the grain too open and would cause spongy iron. To insure the density required for peculiar work the chemical composition must be specified.

TEST BARS.—*Shape of Cross Section.*—Very few realize the influence on strength due to a slight change in proportion of test bar. The results in Fig. 27 were given to me for this paper by the Dodge Manufacturing Company of Mishawaka, Ind. The fracture of each test bar was exactly one square inch area. The supports were 24 inches apart; strength the average of four bars. The analysis of the iron was: Silicon 2.12. Phosphorus .813. Sulphur .081. Manganese .253.

TEST BARS.—*Best Size.*

1 inch square by J. I. Case and committee on malleables.

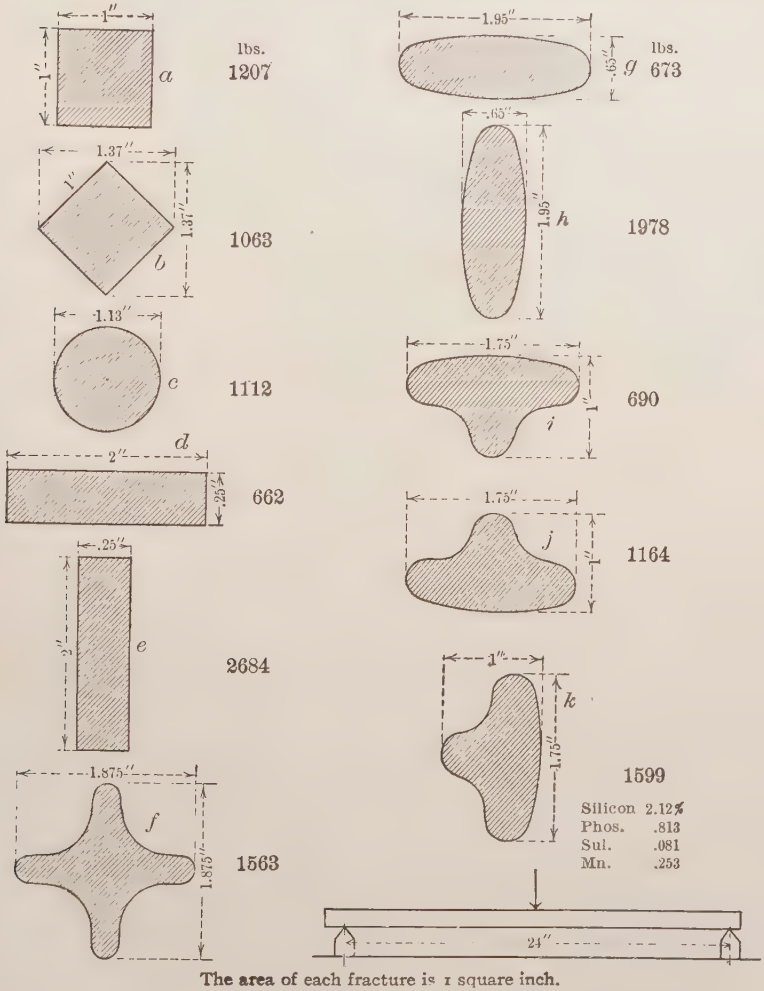
1.13 inches round by Philadelphia & Reading Railway.

1.25 inches round suggested by committee on general castings and for locomotive cylinders.

2 inches by 1 inch by 24 inches by committee on pipe and Lorain Foundry Company and in England.

Tensile strength is always given in terms per square inch of area. The test bar for tensile test should be cast 1.13 inches

diameter, parallel for 2 inches at center, then gradually increasing in size to give taper ends for a firm hold with the grips of the machine. The bar should be tested just as cast, which would give,



The area of each fracture is 1 square inch.

FIG. 27.

without calculation, the tensile strength per square inch of a test bar cast and tested with a square inch section.

If a transverse test bar is cast 1 inch square and tested with

sectional area of two square inches, but the strength per square inch of any of these bars whether tested the narrow or wide side down is not one-half the breaking load, but is the calculated strength of a section one foot long and one inch square.

STRENGTH IN SPECIFICATIONS.—It will be noticed from all figures, Nos. 2 to 23, and from the average American Foundrymen's Association diagrams, that as silicon is increased the strength of heavy castings decreases, but that the strength of a 1-inch square test bar from the same iron increases while in all specifications all heavy and medium castings and also the 1-inch square test bar must be strongest for low silicon. The chemical composition will not account for the extra strength. The Lorain Foundry Company gets it by using special lake ore iron. Some do so by adding steel scrap, and others by using charcoal and other irons with peculiar qualities. There are some pig irons that when mixed with other irons in the cupola give the desired strength and still keep the silicon at 1.30 per cent. Much less expensive irons are needed for medium iron, and quite low-priced irons can be used for soft castings. This is entirely independent of the chemical composition. For example, Series 18, Figs. 6 and 7, has silicon right for medium iron, but it has strength for the heaviest castings. The cupola charge was 500 pounds each, "Swede" (plain), "Pulaski" (No. 2), "Princess" (No. 2), "Kemble" (No. 2), 1,800 pounds scrap, 200 pounds cast iron borings. The test bars were cast at the middle of the heat. A test piece turned to $1\frac{1}{4}$ inches gave a tensile test of 29,040 pounds per square inch. Analysis of test bar was: T. C. 3.33, G. C. 2.83, C. C. .52, Si. 2.05, P. .342, S. .052, Mn. .354. Aside from its favorable composition the very high strength was due to the careful selection of pig irons, but most to the closing the grain with cast iron borings.

If the specifications of J. I. Case T. M. Company be adopted for ordinary foundry iron, it might be well to specify a high grade cupola casting for extra heavy work, and take for such the Lorain strengths 2,800 and 2,600.

For the highest grade of air furnace iron we might take the Lorain for the strongest, and the American Foundrymen's Association, Series *L*, for the highest silicon allowed for medium weights. Strengths 3,800 and 3,200.

SQUARE AND ROUND TEST BARS CAST FLAT OR ON END.—As ordinary castings have flat surfaces and are cast flat, it would seem most natural to use a square test bar cast flat.

The Committee recommended a piece of 10-inch water pipe for a flask. It is impossible to ram a vertical mold with a test bar extending upward without moving the pattern and have the sand packed uniformly. Any variation would produce a test bar of irregular section. In filling a vertical mold with iron the free surface is so small that bubbles of gas cannot reach the surface, but are caught near the walls of the mold.

A square bar cast flat fills with iron so slowly that all bubbles of gas and all impurities that would form spongy spots have ample time to rise to the surface, which will put all flaws in the top surface, where they will not weaken the test bar.

The top of the test bar should be marked, so that it will always be placed in the testing machine as it lay in the mold. In measuring such a square bar the depth can always be distinguished from the breadth, while this would be difficult with a round bar.

A horizontal mold can be rammed more uniformly than if vertical. The Western Foundrymen's Association appointed a large committee to investigate this subject and they reported that in one group all bars cast flat were perfect, while 43 per cent of the round bars cast on end were defective. In another group 18 per cent of the square bars cast flat and 54 per cent of the round bars cast on end were defective.

The Committee of the American Foundrymen's Association say that a round test bar is more difficult to make and test than a square bar.

Professor Woolson, of Columbia University, tested the following test bars of Series 18, Figs. 6 and 7. All bars were cast 1.13 inch diameter from the same ladle and were turned to 1.065 inch diameter, and were tested on an Emery machine.

Round Bars Cast Flat. Tensile Test.

Broke at 25,000 lbs. Small spongy spot.
" " 25,500 " " " "

Average 25,250 " = 28,345 lbs. per sq. in.

sectional area of two square inches, but the strength per square inch of any of these bars whether tested the narrow or wide side down is not one-half the breaking load, but is the calculated strength of a section one foot long and one inch square.

STRENGTH IN SPECIFICATIONS.—It will be noticed from all figures, Nos. 2 to 23, and from the average American Foundrymen's Association diagrams, that as silicon is increased the strength of heavy castings decreases, but that the strength of a 1-inch square test bar from the same iron increases while in all specifications all heavy and medium castings and also the 1-inch square test bar must be strongest for low silicon. The chemical composition will not account for the extra strength. The Lorain Foundry Company gets it by using special lake ore iron. Some do so by adding steel scrap, and others by using charcoal and other irons with peculiar qualities. There are some pig irons that when mixed with other irons in the cupola give the desired strength and still keep the silicon at 1.30 per cent. Much less expensive irons are needed for medium iron, and quite low-priced irons can be used for soft castings. This is entirely independent of the chemical composition. For example, Series 18, Figs. 6 and 7, has silicon right for medium iron, but it has strength for the heaviest castings. The cupola charge was 500 pounds each, "Swede" (plain), "Pulaski" (No. 2), "Princess" (No. 2), "Kemble" (No. 2), 1,800 pounds scrap, 200 pounds cast iron borings. The test bars were cast at the middle of the heat. A test piece turned to $1\frac{1}{4}$ inches gave a tensile test of 29,040 pounds per square inch. Analysis of test bar was: T. C. 3.33, G. C. 2.83, C. C. .52, Si. 2.05, P. .342, S. .052, Mn. .354. Aside from its favorable composition the very high strength was due to the careful selection of pig irons, but most to the closing the grain with cast iron borings.

If the specifications of J. I. Case T. M. Company be adopted for ordinary foundry iron, it might be well to specify a high grade cupola casting for extra heavy work, and take for such the Lorain strengths 2,800 and 2,600.

For the highest grade of air furnace iron we might take the Lorain for the strongest, and the American Foundrymen's Association, Series *L*, for the highest silicon allowed for medium weights. Strengths 3,800 and 3,200.

SQUARE AND ROUND TEST BARS CAST FLAT OR ON END.—As ordinary castings have flat surfaces and are cast flat, it would seem most natural to use a square test bar cast flat.

The Committee recommended a piece of 10-inch water pipe for a flask. It is impossible to ram a vertical mold with a test bar extending upward without moving the pattern and have the sand packed uniformly. Any variation would produce a test bar of irregular section. In filling a vertical mold with iron the free surface is so small that bubbles of gas cannot reach the surface, but are caught near the walls of the mold.

A square bar cast flat fills with iron so slowly that all bubbles of gas and all impurities that would form spongy spots have ample time to rise to the surface, which will put all flaws in the top surface, where they will not weaken the test bar.

The top of the test bar should be marked, so that it will always be placed in the testing machine as it lay in the mold. In measuring such a square bar the depth can always be distinguished from the breadth, while this would be difficult with a round bar.

A horizontal mold can be rammed more uniformly than if vertical. The Western Foundrymen's Association appointed a large committee to investigate this subject and they reported that in one group all bars cast flat were perfect, while 43 per cent of the round bars cast on end were defective. In another group 18 per cent of the square bars cast flat and 54 per cent of the round bars cast on end were defective.

The Committee of the American Foundrymen's Association say that a round test bar is more difficult to make and test than a square bar.

Professor Woolson, of Columbia University, tested the following test bars of Series 18, Figs. 6 and 7. All bars were cast 1.13 inch diameter from the same ladle and were turned to 1.065 inch diameter, and were tested on an Emery machine.

Round Bars Cast Flat. Tensile Test.

Broke at 25,000 lbs. Small spongy spot.
" " 25,500 " " " "

Average 25,250 " = 28,345 lbs. per sq. in.

Round Bars Cast on End. Tensile Test.

Broke at	14,600 lbs.	Bad spongy spot.
" "	16,300 "	Bad blow-hole.
" "	17,400 "	Blow-hole half through.
" "	20,200 "	Small blow-hole.
" "	21,300 "	Small shot in surface.
" "	22,400 "	Solid.
" "	22,500 "	Slight spongy spot.
" "	23,100 "	Solid.*
" "	23,400 "	Slight spongy spot.
" "	23,500 "	Solid.
" "	24,000 "	Solid.*
Average	20,791 " = 23,340 lbs. per sq. in.	

All bars except * had a large number of small blow-holes in the turned surfaces. There was not a flaw in the fracture of any of the large number of square test bars cast flat in this Series 18.

The argument for a round bar is that the grain is more uniform, and that the corners of a square test bar take from the strength of the bar. The average of 38 bars each of American Society of Mechanical Engineers tests (19 series) gave transverse strength of bars of 1 inch area, square 2,361 pounds, round 2,107 pounds. The average of all bars 1 inch area of American Foundrymen's Association tests (*A* to *E*) gave square 2,688, round 2,136 pounds.

Referring to Fig. 27, we see that transverse strength depends largely upon the amount of metal farthest from the neutral axis. The fibre distance of *a* is .50 inch, of *b* .685 inch, but the small portion that was stretched most gave way. The fibre distance of *c* is .565 inch, but the small amount of metal at the lower corner makes *c* weaker than *a*.

The strongest portion of the test bar is its surface. If a hole were bored lengthwise through a test bar, it would not greatly decrease the transverse strength of a test bar.

The large square, Fig. 29, represents the end of a block of cast iron, 9 inches square and 18 inches long. T. C. 2.84, G. C. .60, Cd. C. 2.24, Silicon 1.10, P. .34, S. .09, Mn. .49.

This block was planed into nine parts, and from eight of these were turned test bars of 1 square inch area. The tensile strength

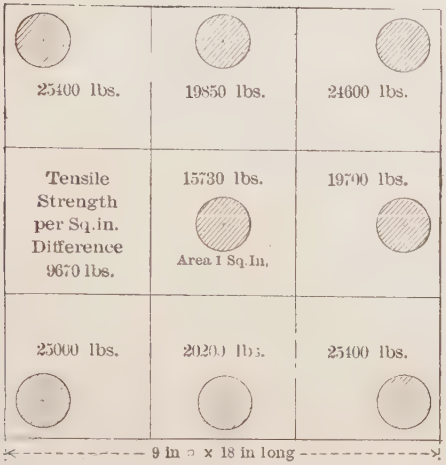


FIG. 29.

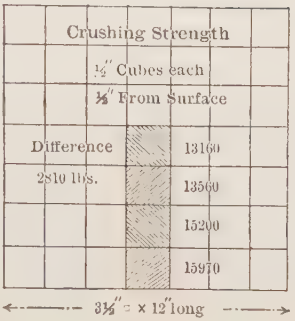


FIG. 30.

of each is given in Fig. 29. The corner is 9,670 pounds stronger than the center, and the corner is 5,000 pounds stronger than the middle portion of the side.

This is also shown in Fig. 30 by compression tests of ½-inch cubes taken at each ½ inch in depth from a 3½-inch square test bar. The center of the side is 2,810 pounds stronger than the center of the casting. It is upon this truss-like distribution of close grain that we depend for strength. See *e*, *f* and *h* of Fig. 27.

For the greatest strength with the least metal we never make a cylindrical casting.

SUMMARY.

A variation of size of a casting causes a great variation in strength, because of the change in the rate of cooling.

A variation of shape of castings which have the same area of cross section causes a great variation in strength.

It is very difficult to calculate the strength of one form or size of test bar from the measured strength of another size.

A test bar should be cast horizontally in the ordinary way and in ordinary sand the same as other castings.

The average strength of at least two test bars cast together should be taken.

The distribution of metal in a square test bar gives a stronger

casting than in a round bar of the same area of cross section, and more nearly represents the ordinary shape of castings.

A test bar 1 inch square is the size and shape in general use.

We think of transverse or tensile strength as so much per square inch.

TABLE III

SPECIFICATIONS SUGGESTED BY THE AUTHOR BASED UPON EXISTING PRACTICE.

CHARACTER OF CASTING.		Silicon range.	Sul. below.	Phos. below.	Mn. below.	Transverse 1 in. sq. x 12 in.	Tensile per sq. inch.	Shrink. 1 in. sq.	Chill 1 in. sq.	Ratio Tensile. Transverse.
Furnace	Heavy	1.20 to 1.50	.085	.24	.37	3,900	38,000	.....	.....	9.74
	Medium	1.50 to 2.00	.085	.68	.04	3,200	31,000	.....	.....	9.69
Cupola	Special — Heavy	1.20 to 1.50	.090	.60	.80	2,600	25,000	.....	.....	9.61
	Special — Medium	1.50 to 2.00	.080	.60	.80	2,400	23,000	.....	.....	9.58
	General — Heavy	1.20 to 1.75	.090	.70	.70	2,400	22,000	.161″	.25″	9.17
	General — Medium	1.40 to 2.00	.085	.70	.70	2,200	20,000	.154″	.15″	9.09
	General — Light	2.20 to 2.80	.085	.70	.70	2,000	18,000	.141″	.05″	9.00
	Chemical Work	1.10 to 1.35	.070	.25	.60	.....	.....	.....	.....	.....
	Brake Shoes	2.00 to 2.50	.150	.70	.70	2,900	28,000	.....	.....	9.69
Chilling Iron		Below 1.00	.....	.....	.....	.....	.....	.....	.....	.....

Transverse test-bars cast and tested 1 in. sq. x 12 inches long. Tensile test-bars cast 1.13 inch diameter and tested as cast.

DISCUSSION.

RICHARD MOLDENKE (by letter).—A few comments would seem necessary for the information of those who desire specifications for testing cast iron to be of commercial as well as scientific application. To begin with, the charge under which the Committee on Testing Cast Iron was organized departed from the original intention of the Zurich Congress of 1895, in that no limitations were placed on the scope of the work, whether this was to be based on existing conditions or not. Furthermore, none of the correspondence touched upon any ordered or implied limitation. The work of the Committee is based upon existing conditions only where these are correct and commercially applicable. Misleading methods, and small special classes of work which might not properly come under a general specification were excluded. The Committee furthermore endeavored to cut out non-essential conditions and tests which would become burdensome and not give additional safety commensurate with the effort expended. For instance the several metallurgists on the Committee, who have had extended experience in foundry practice agreed in omitting the chemical composition, sulphur alone excepted, as the physical strength was a matter of specification. Having both requirements, while praiseworthy in one sense, as giving an additional differentiation of the product, nevertheless imposes expense which seems unfair to the foundry which is not equipped along the most modern lines, and yet turns out excellent product. Mr. Keep is very strong on the chemical composition, yet practical metallurgists are content without most of it, as the physical tests, when made on proper sized and shaped bars, and which must be carried out anyhow, show up the composition quite readily for specification requirements. Where, as Mr. Keep claims, chemical limits are absolutely necessary to insure soundness, well and good, let the purchaser add them, as is his right if he wishes it. Yet metallurgists have found that in these peculiar classes of castings a

Mr. Moldenke.

Mr. Moldenke. matter of more or less scrap in the mixture means a difference in structure not accounted for by chemical means. The Committee, no doubt, acted wisely in confining itself to the more general side of the problem.

Now as to the test-bar. In two instances did the Committee adopt the test-bar in use. The one for pipe, because this was an entirely commercial matter, the makers being perfectly satisfied to adopt a bar free from the objections of the 2 by 1 by 26 inch standard used at present, though they were favored by it, if anything. The engineers, however, under whose care the specifications naturally come thought otherwise, and insisted on the old standard with which they were familiar. Being unacquainted with the characteristics of cast iron, these would have taught them that the round arbitration bar in reality requires a better quality iron to give the tame results when compared mathematically with the rectangular bar, the latter is strengthened in its four corners, and tested on supports double as far apart with consequent greater relative ease in resisting a transverse load.

The other bar is that for "Malleable Castings," 1 by 1 by 14 inches, which has been in constant use since this class of castings has been tested at all. Here we find a situation entirely apart from the gray iron foundry. The bar as cast is white throughout, and hence not artificially strengthened by an increase in combined carbon in the corners. Even if this should be the case when the silicon is a little too high, the subsequent annealing with its conversion of the combined carbon to temper carbon, and its further removal in part, carries with it its own correction.

With gray iron, however, a different situation confronted the Committee. The inch square bar will in all probability always remain a shop test for the approximate valuation of the work made daily. We know that this bar is not even a criterion for castings one inch thick, as coupons cut therefrom will quickly show. It was therefore determined to break away from the various styles of bars used to a greater or less extent by individual concerns, and select such a standard that the objections which could be raised against it both technically and commercially might be a minimum.

The fact that this bar was to be prepared under conditions unusually favorable to the metal so as to bring out its real value,

led the Committee to adopt Mr. Wood's designation, "The Arbi- Mr. Moldenke.
tration Bar." The founder has the privilege of casting as many of these bars for his information as he pleases. For the tests to prove the specifications, the breaking of all the bars called for is in itself the final arbitration. Mr. Keep's criticism that the bar cannot be used to arbitrate as all those cast are broken would not seem to hold.

When the section of the bar was first discussed, it was admitted that the diameter should best be near 2 inches. Subsequent experiment developed the fact that the better grades of castings would be measured by a bar which broke beyond the range of our ordinary testing machines, and hence the diameter was reluctantly reduced to the one adopted. That the results cannot be compared with existing records cuts little figure, as the existing records consist of several elaborately enough conducted tests, but not all of them are above criticism on technical grounds. For instance, every investigator would throw out bars cast flat and which are not known to have been tested as cast. He would call all square bars doubtful. All green sand bars of small sections worthless, and especially discard the much debated half-inch test bar, even for high silicon irons, where the temperature of the iron was comparatively low. What is there then left of the published tests to compare with.

If the molding specifications are gone over carefully, it will be quickly seen that but few bars made previously have had the benefit of a fair deal, and that it is perfectly possible to carry out these molding directions has been demonstrated again and again in the shops under the supervision of the Committee members.

Casting bars on the end requires more skill than molding them flat. This can be soon learned by the molder, and it is expected that an important bar, such as this is to be to the founder, should be molded and poured by the best men in the shop.

The Arbitration Bar is large; has no corners to be affected; is cast in dried sand; is cast vertically, which gives better material than any flat casting for testing purposes; the number required is ample and yet not burdensome; the tensile test is deprecated as unreliable when made on most of the testing machines of the country; analyses for sulphur are provided for, and the limits,

Mr. Moldenke. while liberal, are sufficiently low to keep out inferior iron and coke. Against these manifest advantages stands the fact that we will have to learn to think with values not before impressed upon our minds. Well suppose we begin now, and in a few years we won't mind a bit.

Mr. West. THOS. D. WEST (by letter).—In a study to draw conclusions from Mr. Keep's deduction of the American Society of Mechanical Engineers' tests and those of the American Foundrymen's Association, statements are found that tend to confuse rather than enlighten. We are told on one page that the strength of any size test-bar cannot be calculated by any mathematical formula from the measured strength of another size, and on the next page we have a sentence affirming that such is not the case, and a large table is presented for obtaining the strength of any size of a test-bar from the measured strength of a standard bar. The author then gives rules for finding the strength of any casting by dividing the cubic contents of a casting by the square inches of cooling surface, etc. This is an impracticable proposition. The design of a casting and its treatment in making it, aside from the character of iron in it, are the factors which regulate its strength. Castings for the same purpose can be made from one design that can be cracked with a few raps of a 4-pound hammer, whereas from another design it might require the drop of a 200-pound or heavier ball to break it.

The paper affirms a one-inch square bar to be the standard. I know of no society or committee that has suggested such for approval, and it is but a few years since Mr. Keep held that a one-inch square bar could not indicate the strength of an iron, but that either a smaller or larger bar must be accepted.

In taking up the question of the 1.25-inch diameter arbitration test-bar, Mr. Keep claims such cannot be used to arbitrate a dispute because it is directed that the founder breaks all the bars and no others can be made. He also affirms that the committee of the American Society for Testing Materials had no authority to propose any new tests, but should have confined their indorsements to present or antiquated methods and that the records of 1.25-inch round bar cannot be compared with any existing published records. There is no restriction that I know of to any inspector witnessing the breaking of the bars or having half of any set left for his own pleasure of testing. I may be mistaken, but I do not understand

that the test-bar committee had any instructions not to make research of the most modern methods of testing, or present new ones. If we have overstepped our authority, we should be reprimanded, and the work that has been done should be annulled. It would seem, however, that restrictions to entertain any progress that might have been or could be made, would be evidence that "existing methods" cannot stand the light of research, and I for one object to being on any committee that has instructions preventing their obtaining all possible knowledge of advancement. Mr. Keep's statement, that the record of a 1.25-inch round bar cannot be compared with any existing published records, is like arguing that in making mixtures chemistry should never have been introduced, because of past experience being all in the line of making mixtures by judging fractures. Again, it is not in keeping with the true purpose of test-bars, namely, their ability to define the physical qualities of the iron that goes into a casting. The effect of the design of a casting and its treatment in being molded on its strength is quite another matter, and since it is something that cannot be determined by test-bars, the author's objection to 1.25-inch round bar becomes unsupportable. Mr. West.

The author gives much space to a description of the different kinds and sizes of test-bars in use, with the semblance of advocating their continued application, when the aim of the advance-guard in modern testing is to disparage their use and get the engineering and foundry world to adopt standards only, so that in years to come all results may be intelligently compared, something which is now impossible.

Reference is made to our Committee's recommendation to use a 10-inch pipe for a flask, and objections are raised on the grounds that sand cannot be packed uniformly around a vertically molded test-bar, and that the free surface is so small that bubbles of gas cannot reach the surface for escape and would form imperfections which in the case of square, flat-cast bars would be on the top surface where they could do no harm. A blow-hole or spongy spot in any section of a test-bar is objectionable, and by casting bars on end as our committee advocates there will be less defects than by any other known method. Again, there is no difficulty in obtaining an evenly rammed true cast bar unless the workman has had no experience in using a rammer.

Mr. West.

Mr. Keep claims it is difficult to record the depth and breadth of a round bar in comparison with a square one. With either form a micrometer should be used to indicate any differences of size, and this is as readily done in the one case as in the other.

Reference is made to the Western Foundrymen's Association committee obtaining defective bars. I presented a short discussion at the last meeting of the American Society of Mechanical Engineers showing why such results were secured and should be ignored.

The statement is made that a square test-bar gives a stronger casting than a round bar of the same area of cross-section. This is contrary to all tests I have made or seen recorded. In 1894 I made 100 tests on seven different grades of iron with bars 1.125 inches round and 1 inch square, using three bars of each kind for each test. The different kinds of bars were equal in area as far as it was practical to cast them in the rough. The difference as shown in the following table gives 1,551 pounds in favor of the round bar from the average of seven tests.

TABLE I.

SUMMARY OF STRENGTH AVERAGES OF ROUGH ROUND VS. SQUARE TEST BARS.

Gun metal	Average of	1⅛-inch	round	bars	3,686 lb.
" "	"	1 "	square	"	3,344 "
Chill roll	"	1⅛ "	round	"	2,980 "
" "	"	1 "	square	"	2,432 "
Car wheel	"	1⅛ "	round	"	2,553 "
" "	"	1 "	square	"	2,350 "
Heavy machinery	"	1⅛ "	round	"	2,657 "
" "	"	1 "	square	"	2,504 "
Light machinery	"	1⅛ "	round	"	1,931 "
" "	"	1 "	square	"	1,705 "
Stove plate	"	1⅛ "	round	"	1,798 "
" "	"	1 "	square	"	1,763 "
Sash weight	"	1⅛ "	round	"	1,406 "
" "	"	1 "	square	"	1,362 "

Near the close of Mr. Keep's paper he illustrates a section of a cast-iron bar 9 inches square and 18 inches long. This bar was cut into 9 pieces and the tests taken from the corners and middle portion of the sides of the bars show the corner sections to be 5,000 pounds stronger than the sides. Many other examples have been presented by the writer to illustrate the great objection to the use

of square bars, namely, the greater differences in the density of the material throughout its section as compared with round bars; but none demonstrates more conclusively the inadvisability of using square bars than the illustration presented by Mr. Keep. What engineering society or what engineer would accept specimens for testing steel or wrought iron that presented such irregularities? I know of none, and I believe that, as they come to understand the issue between the advocates of the old and the new forms of test-bars and methods of casting, they will quickly swing to the progressive side and assist in demonstrating that the march is onward, and that what is best must in time prevail. Mr. West.

PIG-IRON FEASTS AND FAMINES: THEIR CAUSES AND HOW TO REGULATE THEM.

By George H. Hull.

Eight times within the last eighty years the industries of the United States have been subjected to the blighting influence of an iron famine. During these famines, all shapes of iron and steel have undergone an enormous advance in prices. These famines have not resulted from the falling off in the volume of production, but from the rapid increase in consumption, and from the impossibility of supplying the demand at the time it occurred. It requires from a year to a year and a half to build a furnace for producing iron. The average stock of iron carried in the United States for the last twenty years has been less than three weeks' production. Under these circumstances whenever the demand for iron has increased largely and quickly, say, 100 per cent within four or five months, it has left an unsatisfied demand—a void, which could not be filled, and in the ensuing struggle among the many consumers to get what little iron was produced over and above what was pledged by contract, these enormous advances have occurred.

If this country during the last eighty years had experienced but two or three such famines, and these had come at odd periods, the iron men of the country might be excusable for not having anticipated them. But these famines have come so often and with such perfect regularity, that many people have endeavored to account for them as the result of some planetary influence upon the human mind, analogous to the effect which the moon has upon the oceans' tide. Others have been able to explain them on a purely business basis. The late Hon. Abram S. Hewitt has, for forty years, predicted these wonderful increases in consumption on the cumulative increase in the per capita consumption, together with the rate of increase in population. In 1855, for instance, the population was about 27,000,000, and we consumed about 100 lbs. per capita; in 1890 it was about 62,000,000 and we consumed

about 300 lbs.; and in 1902 it was about 81,000,000 and we consumed about 500 lbs. per capita. All of Mr. Hewitt's predictions have been more than verified. In his address to the American Institute of Mining Engineers in 1890, when the production was about 9,000,000 tons, he stated that this country would require at least 14,800,000 gross tons of iron per annum by 1900, and made it perfectly clear that there was no more doubt that this result would be realized than that the growth of the country would continue. With such evidences of what was to be expected, it is hard to understand why, in 1895–96–97 producers did not run their furnaces to the utmost capacity, sell as little iron as they could, and pile up as much reserve as possible on which to reap the benefit of the high prices so certain to come.

What they did was exactly the reverse. With less than a million tons of stock on hand, and at a time when the country was on the eve of a return of prosperity which required thirty-seven million tons above the ordinary annual product, meetings were called in nearly every iron producing district for the purpose of bringing about an agreement to restrict production. The furnaces might have piled up a stock equal to several months' production, and still have realized an enormous advance. The experience of Scotland has repeatedly shown that an abundant stock of iron does not prevent a substantial advance in price when demand increases sharply; the stock simply acts as a deterrent to the abnormal and ungovernable advances which spring from freight and rumor, and invariably culminate in disaster to every element in the iron trade. For example, in 1889, the price of iron in Scotland advanced 75 per cent in spite of the fact that the Warrant yards contained a surplus stock equivalent to twelve months' production. On the other hand, had there been no reserve supply on hand, prices would have ascended to an artificial plane, and eventually brought about just such a stagnation in business as that from which we are suffering in this country to-day.

In attempting to explain why a large stock was not accumulated in the United States, in the face of seven such experiences and the painful lessons which they impress, nothing seems to hit the nail so squarely on the head as the view of a certain Scotch ironmaster, who asserts that the Americans are too busy to take long views of business, and as evidence of this cites the fact that our

newspapers (which proverbially give the public what it desires) rarely ever quote prices and conditions back for more than a month or a year. Another Glasgow gentlemen, in discussing the Scotch Pig-Iron Warrant System, said, in effect: "The warrant system has been to us a great educator. Through it we have learned to take broad views of business. We look upon prices and stocks of iron not in the light of a month or a year, but in the light of ten or fifty years. We argue that what has occurred in the past will be repeated in the future, if the same causes exist in the future. We have learned that every few years there is a sudden and great increase in the demand for iron, with a corresponding increase in its price, and we shape all our business calculations to take advantage of these periodic conditions, with little regard to what the conditions are for the current year."

The delusions which result from looking at the iron business in the light of a month or a year are many. For instance, each time that pig iron has experienced several years of low prices in the United States, there has come a general belief that the price of iron could never again reach abnormally high figures. If one attempted to combat this belief, his arguments were swept aside by the declaration that "conditions are different now from what they ever were before," but the high prices have never failed to come again, notwithstanding, and always from the same causes. Conditions are constantly changing in a growing country, but the operation of the law of supply and demand has never changed, and never will.

We have in this country utterly false views of what constitute large and small stocks. With us, 1,000,000 tons of pig iron are regarded as a large stock; 100,000 tons are regarded as a small stock. Neither of these views is necessarily correct.

If the commodity being considered is one the production of which can be increased quickly enough to supply any sudden large demand, then a small quantity may be ample stock; but if it is an article the consumption of which may increase 100 per cent within four or five months, and the production cannot be increased in like proportion under 12 to 13 months, then nothing short of several months' production would be ample stock.

Among all the causes which tend to prevent an accumulation of a reasonable reserve stock of iron in the United States, probably

the most powerful one is the strike and accident clause, which in the last fifteen or twenty years has gradually crept into nearly all contracts for iron and steel. It reads something like this:

"Shipments and deliveries subject to strikes, accidents, deficient transportation, and all other causes unavoidable or beyond our control."

Under shelter of this clause an iron-producer may make contracts for everything he expects to produce a year ahead, and yet not be obliged to carry a single ton of reserve stock. Whereas, without this clause, if he sold ahead, he would be obliged to keep on hand enough stock to insure keeping up his deliveries during any unforeseen interruption in the operation of his works. One powerful influence which results in the accumulation of large reserve stocks of pig iron in Scotland is to be found in the positive and binding nature of all iron contracts made in that country. If anyone fails to deliver, no matter from what cause, he must suffer the loss incurred; hence, no one makes a contract without carrying a reserve stock. Ask anyone who sells to foreign countries for future delivery, whether he is permitted to embody the strike or accident clause in his contracts with foreign buyers. You will find that none of them is. If, for instance, an American exporter sells a million bushels of wheat for shipment to a foreign port a few months ahead, he immediately protects himself against any advance in price by making a contract on exchange for wheat certificates covering a like amount. When he gathers up the grade of wheat needed to fill his contract, he simultaneously sells his exchange contract. If a cotton spinner makes a contract with an exporter for a thousand cases of cotton goods deliverable ahead, he protects himself against advance in cotton by buying cotton contracts on exchange. Before he makes his goods, he picks up the particular grade of cotton he needs, and simultaneously sells his cotton exchange certificates. Thus, in the United States, in nearly every business in the great staples, *except iron and steel*, people protect themselves against advances by making positive exchange contracts.

In Scotland, when anyone makes a contract for work which requires a large amount of iron and steel, he immediately protects himself against the advance in price of these materials by making a contract with an iron dealer for an equal quantity of iron by

warrant; as he needs the iron and steel, he buys it in the open market, and simultaneously sells an equal quantity of his iron warrants.

Strange as it may seem at first glance, prudent business men who deprecate speculation in business are the backbone of exchange dealings in commodities, and it is because of their aversion to speculation that they are so. Anyone, for instance, who takes a contract, deliverable over a long period, involving the use of a large amount of iron and steel, has entered into the most dangerous kind of speculation; but if he protects himself by immediately making an exchange contract for a like amount of iron by warrant, he eliminates this speculative feature, and thereby insures his legitimate business profit, no matter how scarce iron may become or how much it may fluctuate in price during the fulfilment of his contract.

The tendency in Scotland is to use the warrant system and to accumulate reserve stocks of iron, and lessen its extreme fluctuations in price. The tendency of our American custom is just the reverse.

Recently the Hon. Edward Atkinson has predicted that the consumption of iron in the United States will reach 40,000,000 tons per annum between 1910 and 1913. This prediction, like those of Mr. Hewitt, is not a fanciful outburst of imagination; it is simply the result of a mathematical calculation based upon the exact growth of the past, and its fulfilment is as assured as are the future growth and expansion of the country. If in 1910 the stock on hand is one million tons, the production eighteen millions, and the demand forty millions, then the supply will be twenty-one millions short of the demand the first year of the boom, and no human power can prevent another iron famine.

ON THE STRUCTURE OF ALLOYS.

By William Campbell.

The importance of the study of alloys is evident when we consider that most of the metal used to-day is in the form of alloys. Of recent years a great deal of work has been done on the subject, and much progress has been made, due mainly to the great improvements in pyrometry and to the wide application of metallography. About fourteen years ago the Institution of Mechanical Engineers of Great Britain appointed an "Alloys Research Committee," whilst the Société d'Encouragement pour l'Industrie Nationale formed a "Commission des Alliages" shortly afterwards. The former have issued six Reports, whilst the latter have published their work in the Bulletin of the Society and also in a volume entitled "Contributions à l'Etude des Alliages," consisting of sixteen papers. In the publications of the different societies both in this country and abroad, there is an increasing number of papers on the constitution and structure of metals and alloys, for the relation between structure and physical properties is now recognized.

Solidification of Metals.—When a metal cools down to its freezing point it begins to crystallize from a number of centers. The crystals continue to grow until interfered with by neighboring crystals, and so the solid metal is composed of crystals with irregular boundaries, like quartz in a quartzite or calcite in marble, or massive labradorite. Each crystal or grain has a distinct orientation which changes from crystal to crystal, and is well shown when a polished section is etched. The solid portion from a partly solidified mass of bismuth shows this orientation extremely well, whilst the fractures of more or less brittle metals are good illustrations. Fig. 1 magnified 38 diameters shows a fracture of antimony. Part of a single crystal is seen, with its marked cleavage in four directions. The adjoining crystals showed a similar cleavage, but differently oriented. The surfaces of buttons and ingots of many metals show the method of growth very well. The crystals grow in the form of dendrites or skeletons and, owing to contraction during solidification, these are left standing out in relief at the surface. Fig. 2 × 35 shows the surface structure of tin cast on stone. The

junction of parts of two crystals is seen; the dendrites form the skeleton or framework of each crystal and are differently oriented in the two crystals.

Pyrometric Examination.—When a pure metal cools down from the molten state the temperature falls normally until the freezing point is reached. The metal begins to crystallize out (provided surfusion does not occur) and the temperature remains constant until the whole mass is solid, when the temperature again falls normally. A time-temperature cooling curve would show the horizontal break (a) with sharp angles as in Fig. 21, curve 1, indicating that the change from the liquid to the solid state took place at a constant temperature (a). If a trace of impurity were present the curve would no longer show a sharp angle where solidification was complete, but the break (a) would be rounded off as in curve 2.

For metals and alloys with low melting points the mercury thermometer can be used to obtain cooling curves, but for higher temperatures we have to employ other means. Two pyrometers are now in extensive use. First, the Siemens electrical resistance pyrometer, improved by Callendar and Griffiths, makes use of the fact that the resistance of a platinum wire varies with the temperature. The instrument has great sensibility because electrical resistances can be determined with great accuracy. The very accurate work of Heycock and Neville shows what can be done with this method. The second pyrometer is the thermo-electric couple of Le Chatelier, which depends on the electromotive force developed when one junction is heated above the temperature of the other. The thermo-couple is usually composed of wires of platinum and platinum alloyed with 10 per cent rhodium. It has several advantages, such as accuracy at high temperature, small amount of material for determinations and simplicity of autographic recording.

By an autographic recorder such as that of Sir William Roberts-Austen,[1] the tedious work of taking time-temperature readings is overcome. The thermo-couple is connected with a D'Arsonval dead-beat galvanometer. A ray of light from a vertical slit is thrown onto the mirror of the galvanometer and is reflected through a thin horizontal slit in the recorder onto a sensitive plate or paper. The spot of light striking the plate is determined by the dimensions of the two slits. The sensitive plate travels up or

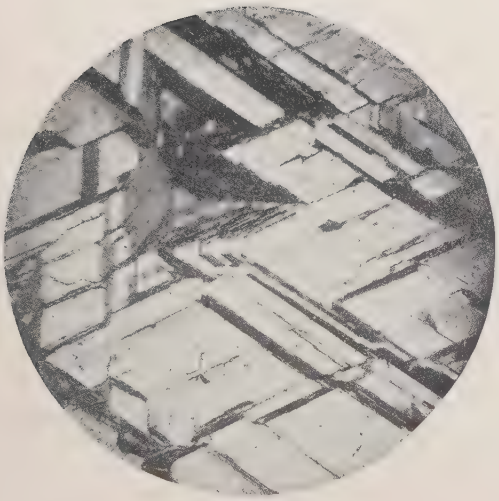


FIG. 1.—Fracture of Antimony. × 38.

FIG. 2.—Surface of Tin. × 35

FIG. 3.—Cu. Ag. Eutectic. × 500.

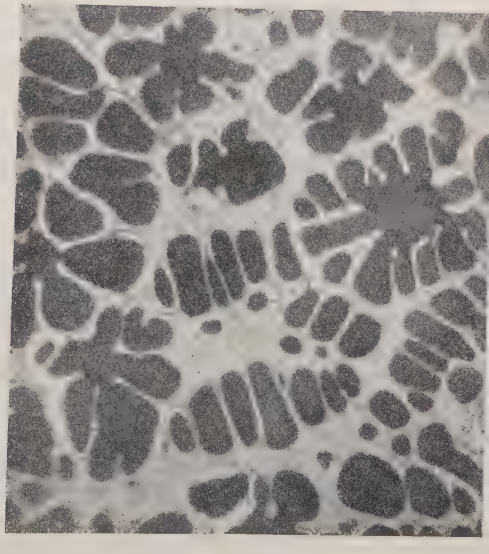


FIG. 4.—Cu. 36, Ag. 64. × 250.

Ostwald has defined solutions as homogeneous mixtures which cannot be separated into their constituent parts by mechanical means. A *solid solution* may therefore be taken as a homogeneous mixture of two or more substances in the solid state. "Isomorphous mixtures or mixed crystals" have been used to define solid solutions, but the meaning can best be illustrated by an example. Glass is a solid solution, for it is homogeneous and even the microscope cannot separate it into its components; whilst these components are present in no fixed ratio as in the case of a chemical compound.

In alloys we find solid solutions of one metal in another or in a definite chemical compound: of a compound in a metal or in another compound. When an alloy of two metals, which when solid form a solid solution, cools down to its freezing point there is an arrest in the cooling; a solid forms, richer in one of the metals than the liquid from which it separates, thus enriching the liquid in the second metal. As the temperature falls more solid separates out, but each successive layer is poorer in the first metal. Diffusion takes place and the solid portion becomes progressively poorer in the first metal until it reaches the composition of the original alloy, when the whole mass is solid. In this way we have one solid with another homogeneously diffused through it. But in many cases we find that solidification is more rapid than diffusion in the solid, and so we have a solid which varies in composition from center to outside, as can be shown by suitably etching, etc. This is especially the case with very many of the alloys of copper. Figs. 8 and 19 show this structure. The cooling curve of a solid solution is shown in Fig. 21, curve 2.

Many metals combine with metals and certain non-metals in atomic proportions to form *definite chemical compounds* with characteristic physical and chemical properties. Copper and antimony form two compounds, the one purple, the other almost white. The purple compound of gold and aluminium is well known. Tin and antimony, copper and aluminium, antimony and aluminium, antimony and zinc, and numerous other metals form definite chemical compounds. Again, we find compounds of iron and carbon, iron and phosphorus, tin and phosphorus, copper and phosphorus, copper and oxygen, etc.

Just as carbon occurs in the three forms, diamond, graphite

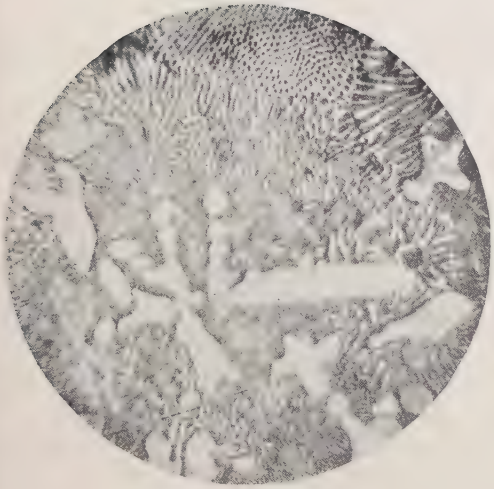


FIG. 5.—Cu. 25, Ag. 75. × 250.

FIG. 6.—Dendrites of Al. in Zn.-Al. Eutectic. × 38.

FIG. 7.—Al.-Zn. Diffusion Alloy. × 38.

FIG. 8.—Al.-Zn. Diffusion Alloy near top. × 38.

and charcoal or phosphorus in the yellow and red varieties, so we find some metals occur in two or more *allotropic modifications*. For instance, iron occurs in three forms, and the change from one to the other has been shown by Roberts-Austen[1] to occur with the evolution or absorption of heat. Osmond[4] has shown that they have different crystalline forms. It is probable that many other metals and some compounds can exist in more than one modification.

Guthrie[5] defined the *eutectic* as a body made up of two or more constituents, which constituents are in such proportion to one another as to give the resultant compound body a minimum temperature of liquefaction—that is, a lower temperature of liquefaction than that given by any other proportion. These proportions are not necessarily in atomic proportions. Eutectic and cryohydrate mean the same thing. The eutectic alloy is therefore that alloy of a series of alloys of two or more metals, with the lowest freezing point. Its freezing point is constant. Its composition is constant and is not necessarily in atomic proportions. It usually consists of a mechanical mixture, as shown in Figs. 3 and 10.

The usual example of a eutectic is that of common salt and water. Pure water freezes at 0° C. If we add a little salt the freezing point is lowered. The more salt added the lower will be the freezing point, until at 23.5 per cent salt we have the solution with the lowest freezing point, at —22° C., which is the eutectic. Further additions of salt raise the freezing point. Between 0 and 23.5 per cent salt we find ice crystallizing out of the mother liquor, and above 23.5 per cent we have salt freezing out. For example, take the 10 per cent solution. Its cooling curve is represented by curve 3, Fig. 21. On cooling, a point (a) was reached at about —8° C., where ice began to separate out, thus enriching the mother liquor in salt. As the temperature fell more ice separated out and the mother liquor became more enriched, until at —22° C. it had the composition of 23.5 per cent salt, when it solidified at the constant temperature (b) or —22° C. as alternate flakes or laminæ of ice and salt. Solutions containing more than 23.5 per cent salt would give a break (a) corresponding to the separation of salt which would impoverish the solution until as before it contained 23.5 per cent salt at —22° C., when it would solidify as alternate flakes of salt and ice, giving rise to the break (b). The freezing

point or cooling curve of the solution containing exactly 23.5 per cent salt would show only *one* break (b), as in Fig. 21, curve 4.

Binary alloys have been divided into three main groups[6] according to their freezing point or equilibrium curves or:

(*a*) The alloys of two metals which form neither chemical compounds nor a series of solid solutions.

(*b*) The alloys of two metals which form a series of solid solutions.

(*c*) The alloys of two metals which form chemical compounds.

Type (*a*). When we study the alloys of two metals A and B, which form neither chemical compounds nor a series of solid solutions, we find the case is the same as that of water and salt. The cooling curves of the pure metals would be shown by curve 1, Fig. 21. The addition of A to B or B to A would lower the freezing points of B and A: the more of the second metal present the lower would be the freezing point, until we arrived at that alloy with the lowest freezing point, or the eutectic. If we plot the freezing points for the various alloys we get two curves intersecting at the eutectic. These two curves are shown in Fig. 22 by the lines AC and BC. C is the eutectic alloy, and its cooling curve is shown in Fig. 21, curve 4. Now any intermediate alloy between A and C or B and C will show two breaks on its cooling curve, as in curve 3, Fig. 21. The upper break (a) corresponds to the separation of the metal A or B, whichever is in excess of the eutectic alloy C, thus enriching the mother liquor in B or A until it has a composition of C per cent when it freezes at the constant temperature (b). The more of A or B present in the alloy, or in other words the nearer the percentage of the alloy to the eutectic ratio, the lower will be the break (a), until at the eutectic alloy it is merged in (b). By plotting the upper breaks (a) for each alloy we get the curves AC and BC in Fig. 22. But the lower break (b) occurs at a constant temperature, where the two curves AC and BC intersect, and therefore is represented in Fig. 22 by the horizontal line through C.

If, when solid, A is completely insoluble in B, and B is completely insoluble in A, then the horizontal eutectic line through C will run from 0 to 100 per cent. But if we have to add a per cent of B to A before we find a lower break in the cooling curve or can see a second constituent under the microscope, and similarly have to add b per cent of A to B before a second constituent appears,

FIG. 9.—Surface of Tin Lead Alloy.

FIG. 11.—Dendrites of Tin in Eutectic.

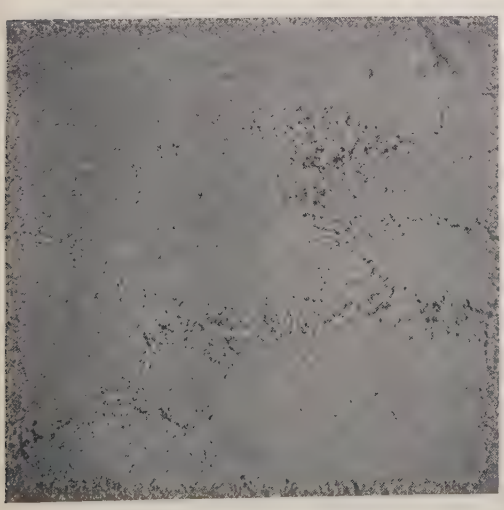


FIG. 10.—Eutectic of Bismuth and Tin.

FIG. 12.—Crystals of Silver in Silver-Lead Eutectic.

then the horizontal line through C runs from a per cent to b per cent as shown in the figure 22. Then alloys up to a per cent of B and b per cent of A will show cooling curves similar to curve 2, Fig. 21, and will be solid solutions. Hence the freezing point curve of this type consists of two inclined branches which intersect at the eutectic angle and the horizontal branch passing through this intersection. In Fig. 22 we have this general curve with the maximum concentration of the solid solutions formed at a per cent and b per cent, respectively. The curves AC and CB form the "liquidus," *i. e.*, above these temperatures everything is liquid. The curves AaCbB form the solidus, *i. e.*, below these temperatures everything is solid; whilst in the areas between the solidus and the liquidus (*i. e.*, ACa and BCb) we have a mixture of liquid and solid. The curve AC denotes the separation of the solid A containing a maximum of a per cent of B in solid solution, the curve BC denotes the separation or freezing out of the B containing a maximum of b per cent of A in solid solution, whilst the line aCb denotes the freezing of the mother liquid or eutectic in the form of a groundmass consisting of a minute conglomerate of A (with a per cent of B in solid solution) and B (with b per cent of A in solid solution). In the particular case where a and b = o we are dealing with pure A and pure B, *i. e.*, B is insoluble in A, and A in B, in the solid state.

The curves Aa and Bb give the composition of the solids A and B as they freeze out, and so a horizontal line drawn at any particular temperature will give the composition of the solid (by the intersection of the horizontal line with Aa or Bb) and the liquid (by its intersection with AC or BC) portions of the alloy which are in equilibrium at that particular temperature.

The alloys of *copper and silver*[5, 7] form a simple series of this kind. If A represents the freezing point of pure copper, 1083° C., and B that of silver at 960° C., the eutectic C occurs at 28.2 per cent Cu and 777.° C., a and b correspond to 1.0 per cent Ag and 1.0 per cent Cu, respectively. All alloys containing between 1.0 and 28.2 per cent Cu consist of dendrites and grains of silver set in an increasing groundmass of the eutectic: those between 1.0 and 71.8 per cent Ag consist of dendrites and grains of copper set in an increasing groundmass of the eutectic. The curve AC corresponds to the freezing out of the copper containing a maximum of 1.0 per

cent Ag in solid solution, whilst BC corresponds to the freezing out of the silver with 1.0 per cent Cu in solid solution.

Fig. 4 × 250 dias. shows the alloy containing 36 per cent Cu, 64 per cent Ag. It contains an excess of copper above the eutectic ratio, and therefore consists of grains and dendrites of copper set in the eutectic composed of alternate flakes or particles of silver and copper. Fig. 5 × 250 shows the alloy containing a slight excess of silver over the eutectic ratio. The white irregular grains are silver, surrounded by the typical eutectic. It will be noticed that the structure of the eutectic varies from coarse to fine, but where we see coarse flakes or threads of copper, they lie next to or in coarse silver, and where the silver is fine the copper is also fine. The reason is evident, for when a coarse flake or thread of copper solidified, a coarse patch of silver froze alongside, in order that the composition of the liquid portion might remain in the eutectic ratio and equilibrium be maintained. This is even better shown in Fig. 3 × 500 dias., where one or two grains of silver are seen, together with the eutectic whose variation in texture is extremely marked. There is another feature in many eutectics which is worthy of notice. It is often found that where there is a large excess of one of the metals in the form of grains and dendrites, the eutectic in their immediate neighborhood is composed entirely of the other metal. The second constituent of the eutectic has been absorbed by the dendrites (of the same metal). This is seen in Fig. 4, where several of the dark dendrites of copper are surrounded by a white envelope of silver. This envelope is very thin and at a short distance away from the dendrites the eutectic has its normal structure. In some alloys which contained about 95 per cent Cu the matrix was found to be composed almost entirely of silver, due to this absorption of the copper by the dendrites. A similar thing has been noticed in many alloys.[8] In annealed low carbon steel, the cementite of the pearlite is often found massive, due to its segregation and the absorption of the ferrite by the surrounding ferrite grains.

The alloys of *lead and tin* form a simple series like those of copper and silver. Their freezing point curve[9] is composed of two inclined branches, the one from the freezing point of lead at 326° C., and the other from the freezing point of tin at 231° C.; they intersect at the eutectic point, 68 per cent tin, 32 per cent lead at

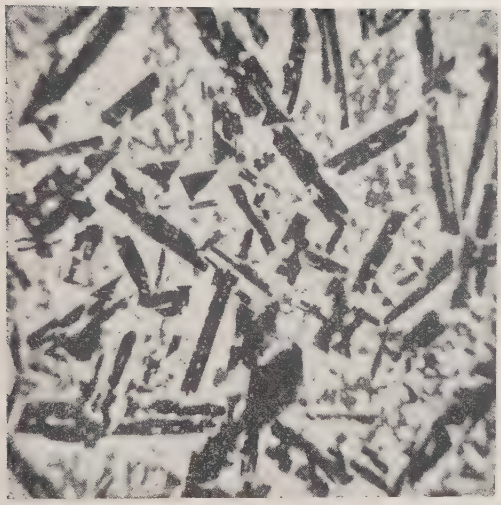


FIG. 13.—Sb. 33, Al. 67. × 16.

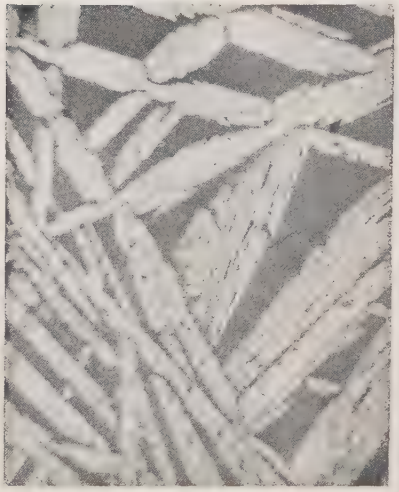


FIG. 14.—As. 20, Sn. 80. × 33.

FIG. 15.—Crystals of Al_2-Cu. × 16.

FIG. 16.—Cu. 5, Sn. 95. × 33.

180° C. Thus between 0 and 68 per cent tin the alloys consist of grains and dendrites of lead surrounded by an increasing matrix which is the eutectic: between 68 per cent and 100 per cent tin the alloys consist of dendrites and grains of tin surrounded by a decreasing matrix. Fig. 9 × 30 dias. shows the surface structure of an alloy of 18 per cent tin, 82 per cent lead. In cooling down a temperature was reached (at 270°) where the whole of the lead could no longer be held in solution. A break in the cooling curve similar to (a) Fig. 21, curve 3, occurred when the lead began to solidify as dendrites; these dendrites continued to grow as the temperature fell and enriched the mother liquor in tin until at 180° C. it had the composition 68 per cent Sn, 32 per cent Pb, when it solidified as the eutectic and gave rise to the horizontal break (b). During solidification, contraction occurred and the lead dendrites were left standing out in relief. The reason why a plumber can so easily "wipe a joint" with plumber's solder is evident. The alloy would begin to separate out crystals of lead at about 245° C., or over 80° C. below the melting point of lead. The mass would remain pasty through a range of 65° C. until at 180° the eutectic solidified. On the other hand, solder containing 2 parts of tin to 1 part of lead melts wholly at 180° C. and has no pasty range. It can be worked with a comparatively cold "iron," and sets clean and white. It is the strongest alloy of the series, having a tenacity of over 9,000 pounds per square inch.

The freezing point curve of *bismuth and tin* consists of two branches, the one from the melting point of bismuth at 266° C., and the other from that of tin, intersecting at the eutectic point 133° C. The eutectic alloy contains about 58 per cent Bi, 42 per cent Sn. The eutectic line aCb, Fig. 22, extends from 10 per cent Bi to about 1 per cent Sn. In other words, tin holds 10 per cent Bi and bismuth holds 1 per cent Sn in solid solution. Fig. 10 × 40 dias. shows the structure of the eutectic alloy. The tin has etched out dark. The variation in texture from coarse to fine gives the mass a coarsely granular structure. To the eye the alloy is markedly "pearly." Fig. 11 × 40 dias. shows the alloy containing 50 per cent Bi, 50 per cent Sn. It contains an excess of tin above the eutectic ratio, and this excess has crystallized out in the form of dendrites which, however, contain about 10 per cent Bi in solid solution. Those alloys between 58 and 100 per cent Bi consist of

an excess of bismuth in the eutectic. In solidifying the bismuth separates out in well-formed crystals, but these are heavier than the mother liquor out of which they separate, and therefore fall to the bottom, forming a layer there. This is the reverse to the formation of ice which is lighter than water and therefore floats to the surface.

The alloys of *silver and lead* form a eutectic containing about 2.8 per cent Ag, which melts at 303° C.[7] It has a characteristic structure, composed of plates of silver arranged in parallel groups. Silver can hold about 4 per cent of lead in solid solution, and so between 100 and 2.8 per cent Ag the alloys consist of dendrites and

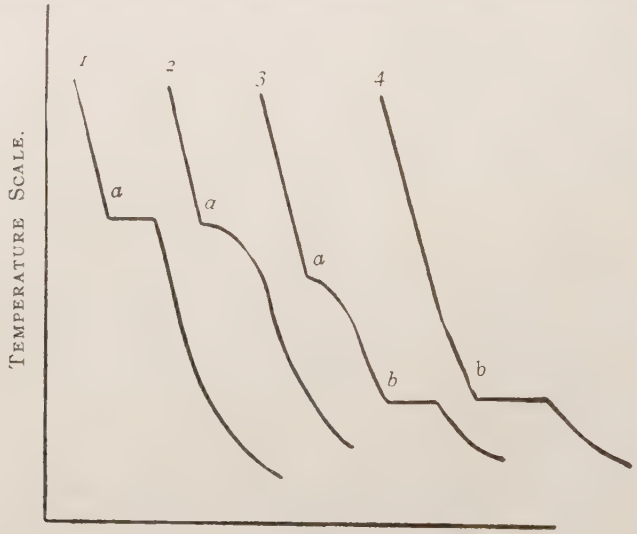


FIG. 21.

skeleton crystals of silver, containing a maximum of 4 per cent Pb in solid solution, surrounded by an increasing eutectic. Fig. 12 shows the alloy containing 10 per cent Ag, 90 per cent Pb, with the characteristic skeleton crystals of silver surrounded by the eutectic. Between 100 and 97.2 per cent Pb the alloys consist of dendrites of lead set in the eutectic. When one of these alloys cools down to its freezing point it begins to separate out dendrites of lead, thus enriching the mother liquor in silver. These dendrites continue to grow until the mother liquid has a content of 2.8 per cent Ag, when it freezes at 303° C., or over 20° C. below the freezing point

FIG. 17.—Ag. 37.5, Sn. 6.25. × 33.

FIG. 18.—Sb. 20, Sn. 80. × 33.

FIG. 19.—Sb. 5, Sn. 95. × 33.

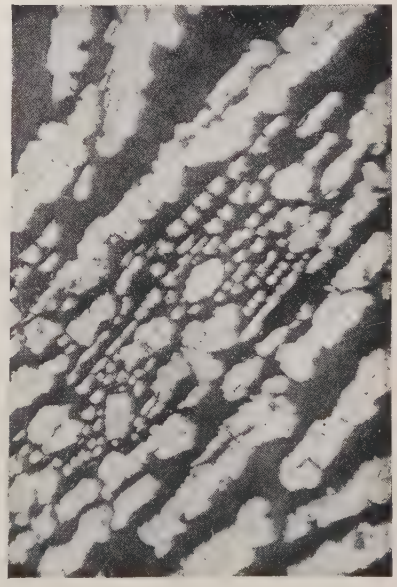


FIG. 20.—Zn. 10, Sb. 22.5, Sn. 67.5. × 30.

of lead. On this depends the Pattinson process for the desilverization of lead. The alloy is melted and allowed to cool slowly. On reaching its freezing point the lead separates out as dendrites, which are skimmed out, thus enriching the bath in silver. The process is repeated, with the addition of fresh lead containing the same amount of silver, and finally two products are obtained, market lead poor in silver, and lead rich enough in silver to be cupelled.

Further examples of alloys forming neither chemical compounds nor a series of solid solutions are: Zinc and aluminium, eutectic contains 5 per cent Al and melts at 380° C.; zinc and tin, eutectic contains 8 per cent Zn and melts at 205° C.; lead and antimony,[10] eutectic contains 12.5 per cent Sb and melts at 247° C.; zinc and cadmium,[11] eutectic contains 17.5 per cent Zn and melts at 265° C.

When examining a series of alloys, a simple method can often be employed whereby the whole series can be obtained in one section.[12] The two metals are melted in separate crucibles and the lighter is carefully poured onto the heavier and the whole is allowed to solidify slowly. Diffusion takes place, and on cutting a section we have the whole series from 0 to 100 per cent. For example, when such a diffusion alloy is made with aluminium and zinc, we find at the base the characteristic grains of zinc. At a short distance higher up the eutectic makes its appearance. It rapidly increases and the zinc grains become well-marked dendrites, which become smaller and finally disappear. The alloy has then the well-marked structure of the eutectic and contains about 5 per cent Al. On passing upwards dendrites of aluminium make their appearance, as is shown in Fig. 6 × 38 dias. As the eutectic diminishes, the dendrites of aluminium grow larger and become less distinct. Fig. 7 × 38 dias. shows the section where the eutectic has become merely an envelope round the massive dendrites of aluminium, while Fig. 8 × 38 dias. shows the section near the top of the alloy in which the eutectic has been reduced to a few isolated black dots. Above this point it disappears. Figs. 7 and 8 show that the dendrites and grains are not pure aluminium, but contain some zinc in solid solution. Owing to imperfect diffusion they are purer in their centers, as is shown by the marked darkening of their borders on etching (with dilute nitric acid).

Type (*b*). Coming next to the alloys of two metals which form a series of solid solutions. Our two metals A and B form

solid solutions in all proportions. As before, the cooling curves of the pure metals can be represented by curve 1, Fig. 21, but any intermediate alloy has a cooling curve represented by curve 2, Fig. 21. The freezing point curve for the whole series consists of a continuous curve joining the freezing points of the two metals A and B. This is shown by the curve AabB in Fig. 23. This is the "liquidus," whilst AcdB represents the solidus. Thus above AabB the alloys are liquid, below AcdB the series are solid, whilst between the two curves in the area AabBdc we have a mixture of liquid and solid. An alloy with a composition represented by the vertical line ad has a freezing range from a to d. As a horizontal line cutting the solidus and the liquidus at any particular tempera-

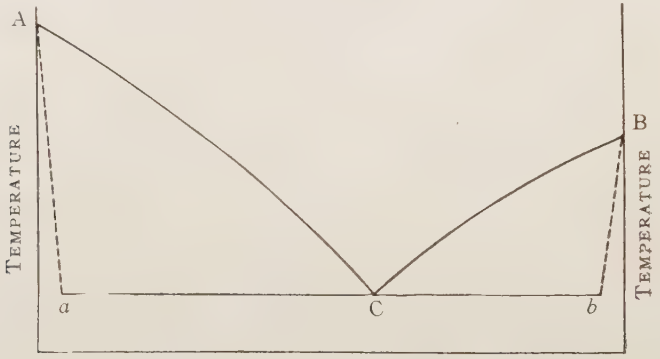


FIG. 22

ture gives the composition of the solid and liquid portions in equilibrium at that particular temperature, it follows that the alloy a will commence to freeze by the separation of a solid having the composition c. As the temperature falls the composition of the solid passes from c to d, whilst that of the liquid passes from a to b, the solid increasing and the liquid decreasing until at the temperature db the whole alloy is solid. The alloys of gold and silver,[18] and probably of antimony and bismuth, are examples of this class of alloys.

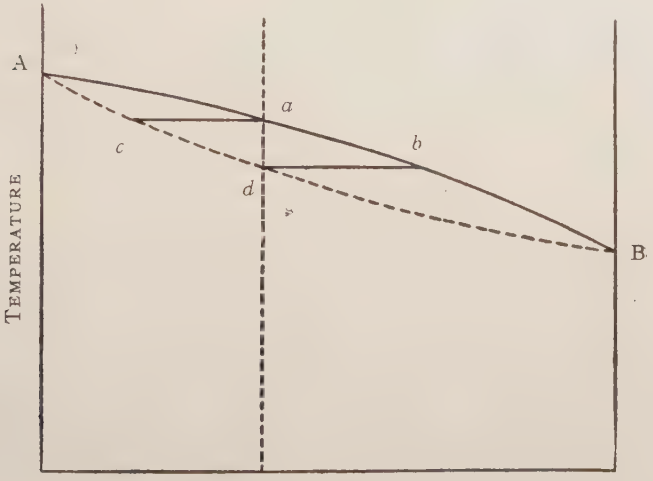
Type (*c*). This group embraces the alloys of those metals which form chemical compounds with one another. The simplest case is that in which there is one compound which forms a simple series of alloys with each of the metals. The freezing point curve

is simply a combination of two curves similar to that in Fig. 22. There are two eutectics. If the two metals A and B combine to form a compound A_xB_y, this compound acts as a metal, and we may have:

(1) The excess of A or the compound A_xB_y in a groundmass which is the eutectic of A and A_xB_y.

(2) The excess of B or the compound A_xB_y in a groundmass which is the eutectic of B and A_xB_y. Thus in (1) we find no free B, whilst in (2) we find no free A.

The alloys of zinc and antimony are probably the best example of this case. Copper and antimony, with the purple compound



0% PERCENTAGE COMPOSITION. 100%B.
100% FIG. 23 0%A.

$SbCu_2$, are usually given, but Stead[14] has shown the presence of a second compound, $SbCu_3$, which is white, whilst Baykoff[15] finds that part of the series rearranges itself in the solid.

In most cases, however, where two metals combine to form chemical compounds a complex series of alloys results, as a few examples will show.

Copper and aluminium[16] form a compound Al_2Cu, and between pure aluminium and the compound Al_2Cu we have a simple series of alloys with a eutectic at about 32 per cent Cu. Thus between 0 per cent and 32 per cent Cu the alloys consist of dendrites and

grains of aluminium set in an increasing groundmass which is the eutectic of Al and Al_2Cu. Fig. 11 can be taken as a type of structure. Between 32 per cent Cu and Al_2Cu the alloys consist of crystals of the compound set in a decreasing groundmass or eutectic of Al and Al_2Cu. Fig. 15 × 16 dias. shows the surface structure of an ingot containing 51 per cent Cu, 49 per cent Al. The pure compound would contain 54 per cent Cu. The well-defined crystals of the compound have grown, contraction took place on cooling, the mother liquor sank beneath the surface, leaving the crystals in relief. A section shows these crystals surrounded by the eutectic. When the copper is increased above that of Al_2Cu a complicated series results with two higher compounds and changes in the solid similar to those found in the steel series.

Copper and tin[17] form three compounds, viz: CuSn, Cu_3Sn and Cu_4Sn. The eutectic alloy of tin and CuSn occurs at 1 per cent Cu. Between 0 per cent and 1 per cent Cu the alloys consist of dendrites and grains of tin set in the eutectic of tin and SnCu. Figs. 6 and 11 represent this part of the series. Between 1 per cent and about 8 per cent Cu we find needle-shaped crystals of SnCu forming characteristic six-rayed groups, set in the eutectic. Fig. 16×33 dias. shows the alloy containing 5 per cent Cu, in which the crystals of the compound are seen. (They are important as being one of the constituents of many bearing metals.) The groundmass is the eutectic of tin and SnCu. Above 8 per cent Cu the series becomes complicated because the first solid to form is $SnCu_3$, which at a lower temperature reacts with the mother liquor to form CuSn.

At the copper end of the series, between 0 and 25 per cent Sn, the alloys consist of dendrites and grains of copper set in an increasing groundmass with a eutectic structure. Fig. 4 may be taken as the type of structure. The copper dendrites, however, contain over 5 per cent of tin in solid solution. The groundmass is composed of alternate laminæ of copper containing some tin in solid solution and the compound $SnCu_4$. It solidified as a solid solution and at a lower temperature rearranged itself into Cu and $SnCu_4$. To all such groundmasses which owe their structure to change in the solid, Howe has given the name "eutectoid." Between the eutectoid point (25 per cent Sn, 75 per cent Cu) and the compound Cu_4Sn, the alloys solidify as solid solutions and at a lower temperature rearrange themselves into Cu_4Sn and the

eutectoid. Similarly between Cu_4Sn (68.2 per cent Cu) and Cu_3Sn (61.8 per cent Cu) the alloys solidify as solid solutions, but at a lower temperature rearrange themselves into the compounds Cu_3Sn and Cu_4Sn. In this series belongs speculum metal. As in steel, so here this change in the solid is of the utmost importance, for heat treatment and rate of cooling have the greatest effect on structure, and on structure depend to a great extent the physical and mechanical properties.

Silver and tin[18] form a compound Ag_2Sn at 65 per cent Ag, and between this point and pure tin we have a simple series of alloys with a eutectic at 3.5 per cent Ag. Thus between 0 and 3.5 per cent Ag the alloys consist of dendrites and grains of tin in an increasing groundmass which is the eutectic of tin and Ag_2Sn. Between 3.5 per cent Ag and 65 per cent Ag the alloys consist first of needles, then of grains and dendrites of the compound surrounded by a groundmass which is the eutectic of Sn and Ag_2Sn. Fig. 17 × 33 V shows the alloy containing 37.5 per cent Ag, 62.5 per cent Sn, in which the bright dendrites of the compound are seen set in the dark etching eutectic. Between Ag_2Sn and pure silver the alloys consist of isomorphous mixtures of Ag and Ag_2Sn.

Antimony and aluminium[19] form a compound at 81.5 per cent Sb corresponding to the formula SbAl. It is remarkable, for it melts at a temperature far above the melting points of its constituents. Its melting point is 1075° C. The series can be divided into two groups: (1) 0–81.5 per cent antimony, consisting of the alloys of SbAl and Al; (2) 81.5–100 per cent antimony, consisting of the alloys of SbAl and Sb. Fig. 13 × 16 shows the alloy containing 33 per cent Sb, 67 per cent Al, in which the blackish purple crystals of the compound are seen set in the aluminium-rich groundmass. The alloys of antimony and aluminium rapidly oxidize in the air and soon disintegrate, those containing much of the compound becoming a fine black powder.

Tin and arsenic[10] form a compound having the composition Sn_3As_2. It crystallizes out in thick rough plates, as shown in Fig. 14, which is the alloy containing 20 per cent As, the groundmass melting some 4° C. above that of pure tin and containing some arsenic in solid solution. *Tin and phosphorus* form a similar compound, Sn_3P_2.

Tin and antimony[10] form an important series of alloys which have been used for bearing metals. The alloys between 0 and 7.5 per cent Sb are solid solutions of the compound SbSn in tin, and crystallize out in forms isomorphous with tin. Fig. 19 × 33 shows the alloy containing 5 per cent Sb, 95 per cent Sn, which is a type of this series. With increase in antimony the freezing point increases also from 232° C., that of tin, to 256° C., that of the alloy containing 7.5 per cent Sb. Above this point bright white cubes make their appearance. According to Stead they correspond to SbSn. Fig. 18 × 33 shows the alloy containing 20 per cent Sb, 80 per cent Sn. It consists of bright white cubes of the compound set in a groundmass with a structure the same as that shown in Fig. 19, and isomorphous with tin. These bright cubes are lighter than the mother liquor out of which they freeze, and therefore they float to the surface and form a layer there like ice on water. The cubes increase with the antimony in the alloy and at about 45 per cent Sb begin to interfere and lose their cubic shape with marked increase in brittleness. At about 52 per cent Sb, before the groundmass has disappeared, the crystals begin to show a harder core of antimony, which increases and finally occupies the whole field.

Examples of *ternary alloys*. A bearing metal very much in use consists of 5.5 per cent copper, 11 per cent antimony, 83.5 per cent tin. Under the microscope three constituents are seen: (1) Bright needles of the compound CuSn, as seen in Fig. 16; (2) bright hard cubes of SbSn, shown in Fig. 18; (3) a tin-rich groundmass which is plastic enough to yield to the axle, and in which the two hard constituents are imbedded.

By substituting zinc for copper a marked change is produced in the structure of the alloy. The compound SbSn no longer has its cubic shape, but has grown on and around a distinct harder core rich in zinc. Fig. 20 × 30 dias. shows an alloy containing 10 per cent Zn, 22.5 per cent Sb, 67.5 per cent Sn. The hard bright constituent is seen to be composite and consists of the compound SbSn with a zinc-rich core, probably the compound of zinc and antimony.

If we replace the zinc by lead we get a third type of structure. We find the bright cubes of the compound SbSn set in a groundmass composed of grains and dendrites of tin surrounded by the eutectic. (See Fig. 11.)

Antifriction metals[20] are usually composed of three or more metals and give a wide field for research, but until the binary alloys have been worked out it is difficult and often impossible to interpret the structures met with in ternary alloys.

From the above examples it will be seen that alloys possess distinct and definite structures whose influence on the physical and mechanical properties is extreme. In many cases the rate of change from the liquid to the solid state will determine the properties of an alloy. But in others there are profound changes which occur far below that point at which the alloy becomes solid. As examples of such changes in the solid state we have certain of the alloys of copper and tin, copper and aluminium, copper and antimony, and lastly, iron and carbon. The great changes brought about in steel, etc., by quenching, tempering, annealing and the like, are simply those of structure or change of state, and if by the microscope and pyrometer we can follow those changes we can soon control them.

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DISCUSSION.

The President. THE PRESIDENT.—Possibly Mr. Campbell would be willing to say a few words as to the method by which eutectics are determined.

Mr. Campbell. WM. CAMPBELL.—I do not know how the prehistoric plumber and tinsmith discovered that the eutectic of lead and tin consisted of two parts of lead and one of tin, but they were certainly aware of the fact that this alloy was the solder that froze at the lowest temperature. With it they could get a cleaner joint than with any other alloy of tin and lead. The ordinary method of finding the eutectic of two (or more) metals is as follows: A large quantity of the two metals is melted in a crucible and allowed to slowly cool. When the greater part of this alloy is solid the small amount of mother liquid is poured off. This part is remelted and allowed to solidify and, as before, when the greater part has crystallized out, the remaining liquid is poured off. This portion will have approximately the composition of the eutectic.

Mr. Clamer. G. H. CLAMER.—The eutectic constituent of alloys does not seem to be very well understood generally, and a few words of explanation would probably not be amiss here.

I think the best way of understanding this constituent is to imagine a body of sea water evaporated. A mixing of elements here in various proportions form chemical compounds, and if we imagine this aqueous solution of these compounds evaporated, we will have them crystallized out from the solution one after the other, according to their solubility. Upon further evaporation we finally get a saturated solution of all these different salts, commonly known as the mother liquor. This in alloys is what has been termed "Eutectic." Eutectic is a saturated alloy or saturated combination of metals. In the tin and copper alloy, for instance, when the same is allowed to cool from the molten condition, according to the proportions in which these metals exist there is separated out first the element or combination of metals which has the highest fusing point. In alloys where copper pre-

dominates, the first solidification is pure copper. This is then followed by the various copper and tin chemically combined compounds, until finally there is left a saturated solution of copper with tin and tin with copper. This is the eutectic of the alloy; the copper first solidifying at a temperature of approximately 2,000° F., and the intervening compounds at various temperatures, until finally the eutectic solidifies at approximately 930°. The chemical constitution of this eutectic has been shown to be approximately 73 per cent. copper and 27 per cent. tin. Mr. Clamer.

The plumbers' solder referred to by Mr. Campbell gives a very interesting example of eutectic which is put to practical application. When wiping a plumber's joint, the lead will first crystallize, and dispersed throughout the still liquid eutectic forms a pasty mass. The plumber has all the time it takes to cool, from the crystallizing point of the lead to the freezing point of the eutectic, to wipe the joint, until finally the material reaches the freezing point of the eutectic, and the entire mass is solidified. This represents a change of from probably 100° to 200° or more.

The combination of metals presents a very interesting subject, and there is much yet to be learned. Some metals will combine chemically, the same as the elements combine to make salts, others are simply solutions of one metal in the other, and others present very much more complicated combinations.

A NEW CHUCK FOR HOLDING SHORT TEST PIECES.

By T. D. Lynch.

There is probably no other place where short practical methods are conceived and made use of more effectively than in the laboratories of modern manufacturing concerns where great quantities of raw material are used. Managers are rapidly becoming more and more in sympathy with the fact that materials are of first importance in both design and construction, and it is a growing necessity for users to make a study of the materials entering into their products. This study is being conducted in a most practical way by nearly all large users, demonstrating the qualities affecting the special duties for which the material is intended, and the economical ways devised for testing are often superior to commercial tests.

These tests bring those of us who are users of a great variety of materials in touch with such characteristics as affect our work and thus enable us to use the most economical material available for a given purpose. Such tests and devices are conducted by busy men, who seldom have time to write for publication. Therefore many most worthy designs of apparatus, and methods of quick, accurate testing are not extended to other laboratories or, more frequently, the whole scheme is covered by a patent limiting its use to the few.

It has suggested itself to me, that if the members of this Society would give in detail such practical methods as they have established, used and found valuable to themselves, much additional information might well be provided for our publications, and in that way each of us would get the benefit of the other man's experiences, and *vice versa*. This is already being done in a measure and in order to give additional impetus, I wish to describe a chuck designed to hold physical test pieces without the usual necessity of threading the ends. By this means we make tests of standard dimensions of the tested portion, and as short as $2\frac{7}{8}$ inches in

total length. I have deviated slightly in the dimensions of the test piece from that adopted by this Society as its standard. The 2-inch gauge length is maintained, but 0.505-inch diameter is adopted instead of 0.5 diameter on account of convenience of calculation. This in itself affects the holding device in no way, and it is found that 0.505-inch diameter is just as easy to machine as 0.5 inch, making 0.2 instead of 0.1963 square inch area, rendering the computation simple and correspondingly less liable to error.

This chuck has been in constant use in the Material Testing Department of the Westinghouse Electric and Manufacturing Company, East Pittsburg, Pa., for about two years; it is extremely simple, easy to apply, gives perfect alignment, saves threading, permits of tests from minimum stock, and may be described briefly as follows:

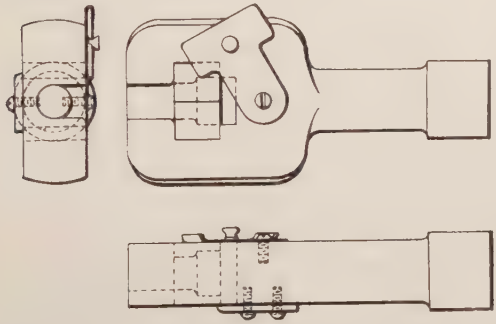


FIG 1.

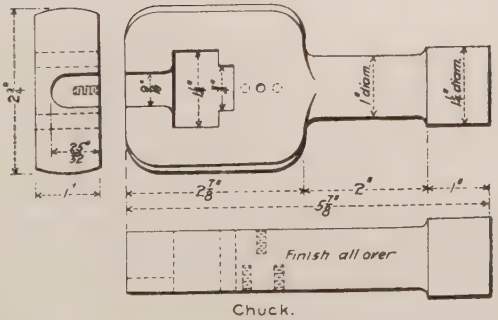


FIG 2.

Fig. 1* shows the assembled chuck; Figs. 2 and 3 show in detail the component parts.

The head and neck are similar to the old chuck for the standard threaded-end test pieces.

The body is $2\frac{7}{8}$ by $2\frac{3}{4}$ by 1 inch, with a chamber $1\frac{1}{4}$ by $\frac{3}{4}$ inch, extending through the body to receive the split bushing. Adjacent to this and over it is provided another chamber $\frac{3}{4}$ by $\frac{1}{4}$ inch to receive the end of the test piece that may extend above the bushing.

* Acknowledgment is made to the *Railroad Gazette* for the cuts used in this paper.

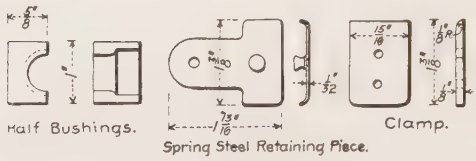


FIG 3.

A slotted hole extends from the bushing chamber to the bottom of the chuck to provide space for the test to assume proper alignment.

The half bushings are made of tool steel and so designed that the shoulder of the test piece will fit snugly into them when put together. The outside of the half bushing is accurately made so that when put together in pairs they will slip easily into the chamber.

A clamp is fitted to the back with two small screws and extends over the end of the chamber to hold the bushings when they are pushed home.

A spring steel retaining piece is attached to the front of the body by means of one screw, permitting a side motion; when drawn down it holds the bushings and test firmly in place, and when pushed to one side the bushings can be readily removed.

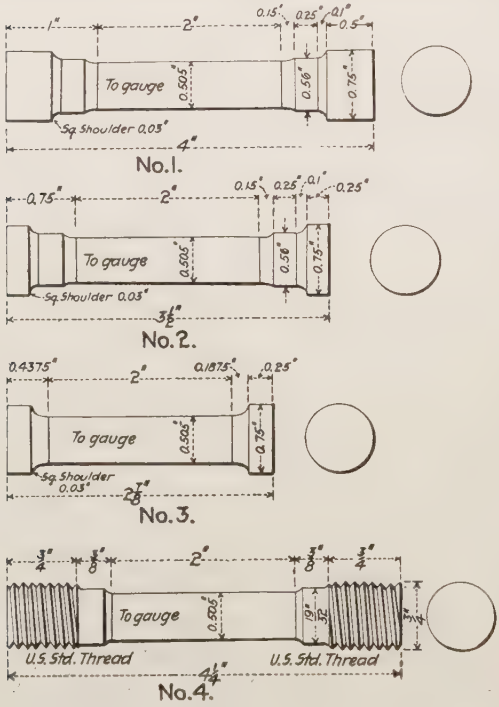


FIG 4.

Fig. 4 illustrates three styles of holding-heads for specimens, three of which have been used successfully in this chuck.

No. 1 has a total length of 4 inches, and is recommended when there is plenty of stock.

No. 2 has a total length of $3\frac{1}{2}$ inches, and shows the proper proportion when the tests are but $3\frac{1}{2}$ inches long.

No. 3 has a total length of $2\frac{7}{8}$ inches, and is the minimum length so far used in this chuck, maintaining a constant test section of 2-inch gauge length and 0.505-inch diameter. There has been no noticeable difference in the results of tests due to the variations in total length. Even with the shortest piece, all tests so far conducted, have broken near the middle of the tested portion except for local flaws such as would affect any test regardless of holding devices.

No. 4 has a total length of $4\frac{1}{4}$ inches with threaded ends and corresponds in every way to the standard adopted by this Society, except the diameter is 0.505 inch instead of 0.5 inch. This was used by us with the ordinary threaded chuck, until replaced two years ago by the one just described.

THE COMMERCIAL TESTING OF SHEET STEEL FOR ELECTRICAL PURPOSES.

By C. E. Skinner.

At the present time the rate of consumption of sheet steel in the manufacture of electrical apparatus in the United States alone is probably not less than one hundred million pounds per year. Assuming that 20 per cent of this material is subjected to the conditions under which the so-called iron loss occurs and that this loss is one and one-half watts per pound, we find we have a total loss of 30,000 K.W. (40,000 H.P.), or an amount of power approaching the output of the largest single electrical power station in existence. At the rate of $25 per horse-power per year, this represents a money value of $1,000,000. This loss manifests itself as heat in the apparatus, and therefore serves no useful purpose, but forms one of the limitations to the output of the apparatus.

The losses referred to are the hysteresis and eddy current losses, more commonly combined under the general term "iron loss." This loss occurs in all magnetic material which is subjected to alternating magnetic stresses, the amount of the loss in any given material depending upon a number of conditions which will be referred to later.

In general, the following must be taken into consideration in connection with the testing of sheet steel for electrical purposes:

1. The losses in different sheet steels vary greatly with the chemical composition and with the physical condition due to the heat treatment and the mechanical working which the steel has received.

2. In most sheet steel the losses may be reduced by annealing to a relatively small value.

3. Nearly all steels, when the losses are reduced to a low value by annealing, are subject in a greater or less degree to aging, or increase in loss, due to the influence of comparatively low temperatures.

4. The permeability of all steels which may be rolled commercially differs by a comparatively small amount, no matter what their condition with respect to annealing.

5. In all commercial sheet steels the physical characteristics are well above the service requirements.

The commercial testing of sheet steel for electrical purposes therefore resolves itself into:

(*a*) Chemical tests to determine the composition of the steel.

(*b*) Electrical tests to determine the losses in the steel after punching, before and after annealing.

(*c*) Electrical tests to determine whether aging, or increase in the losses, occurs when the steel is subjected to moderate temperatures.

(*d*) Tests for permeability.

(*a*) CHEMICAL TESTS.

Sheet steel used for electrical purposes is always a very mild steel, the carbon rarely being above 0.15 per cent, the phosphorus, sulphur, silicon and manganese also usually being kept quite low. The composition may vary over comparatively wide limits and the steel still fulfill the necessary conditions as to quality. One or two complete analyses from each heat and occasional check analyses from the sheet before and after annealing are usually sufficient for the purpose.

(*b*) ELECTRICAL TESTS.

By far the most important tests are those to determine the hysteresis and eddy current losses, either separately or combined, the amount of these losses showing the electrical quality of the steel.

Hysteresis Loss.—Hysteresis loss may be defined as the work done in reversing the magnetism in the steel, and it may be considered as the molecular friction due to the reversal of the magnetism, this friction manifesting itself as heat. The amount of hysteresis in a given steel varies with the composition, with the hardness, with the maximum induction at which the steel is worked, with the frequency of reversal of magnetism, with the wave form of the applied electromotive force used in the test, and with the

temperature of the test sample. The hysteresis loss is greater as a rule in hard steels than in soft steels. It varies approximately as the 1.6 power of the induction, and directly as the frequency. It is greater with a flat top or a sine wave electromotive force than with a peaked or a saw-toothed wave.

Several instruments have been devised for measuring the hysteresis loss in steel. The Ewing Hysteresis Meter is probably the best known and most used. With this instrument, samples weighing only a few ounces are required for the test, the measurements being made at a fixed induction and the instrument calibrated so as to read direct in some convenient unit. A complete description of this instrument and the method of its working may be found in the Journal of the Institution of Electrical Engineers (London), Vol. 24, page 398. Other instruments employing the same general principle or entirely different methods are available for measuring hysteresis loss, but as these may all be found in the text-books of the day their description will not be given here.

Hysteresis measurements are valuable as showing the effects of annealing, but as it is very difficult in practice to separate the hysteresis loss from the eddy current loss, and as the total loss under working conditions is the point of vital importance to the user of the steel, measurements of hysteresis loss alone become, in general, of secondary importance.

Eddy Current Loss.—By eddy current loss is meant the loss due to the circulation of electric currents in the sheets themselves and between adjacent sheets, due to the steel acting as a conductor in an alternating magnetic field. The eddy current loss varies inversely as the ohmic resistance, directly as the square of the induction, and decreases as the temperature increases. It is greater in thick sheets than in thin sheets, and is greater as the insulation between adjacent sheets is less. Tests for eddy current loss alone are difficult to make, and as far as the writer is aware, no instrument has been devised for this purpose. An approximation of the amount of eddy current loss in a given sample can be reached by measuring the total losses at different inductions and assuming that the eddy current loss varies as the square of the induction and the hysteresis loss as the 1.6 power of the induction. For special investigations the eddy current loss is sometimes calculated in this way, but commercially such tests are rarely considered.

The measurement of the total losses under working conditions gives the best index of the electrical quality of the steel. As the total loss is made up of the combined hysteresis and eddy current losses it is subject to all the variations of each as outlined above.

Measurement of Total Losses.—In commercial routine testing as followed out in the sheet steel testing department of the Westinghouse Electric and Manufacturing Company, of which the writer has charge, two separate methods, which may be designated as the transformer method and the armature method, have been found very satisfactory. In both these methods of testing, commercial conditions of operation have been aimed at in order that the results obtained might be checked with the tests made on similar material in commercial apparatus. The test samples have also been so chosen that they will be available for commercial apparatus later, this effecting a considerable saving of material where many tests are made.

The transformer method has been so called for the reason that the test sample consists of about ten pounds of punchings of a standard transformer plate, these punchings being built up in the same manner as when used in the transformer. For convenience in handling and winding the test sample, a block carrying the coil has been devised, this block being split and the wires of the coil continued between the two parts by means of mercury cups and contacts. By this means, samples which are built up or plates which are not split may be used and placed on the testing block with the winding in place in a few seconds. The routine tests on such samples consist in measuring the total losses at a given induction and frequency by means of a wattmeter. For special tests the induction, frequency, wave form, and the pressure on the sample are varied as desired.

This test is used regularly for judging the quality of each lot of steel as received, for judging the quality of the annealing of each furnace load of material, and for determining the aging on all classes of material. From twenty to fifty tests per day are made on this apparatus by one operator. In making tests of this kind the wave form of the applied voltage must be known and should preferably be a sine wave; correction must be made for the copper loss in the magnetizing coil; correction must be made for the losses in the voltmeter and wattmeter, or these losses must be eliminated

in the measurements; the test samples must be at approximately uniform temperature.

The armature method is so called for the reason that the test sample consists of standard armature punchings, which are revolved in a standard form of dynamo field. The measurements are made by means of a spring dynamometer. A photograph of a testing device of this kind is shown in Fig. 1,* and a detail drawing of the

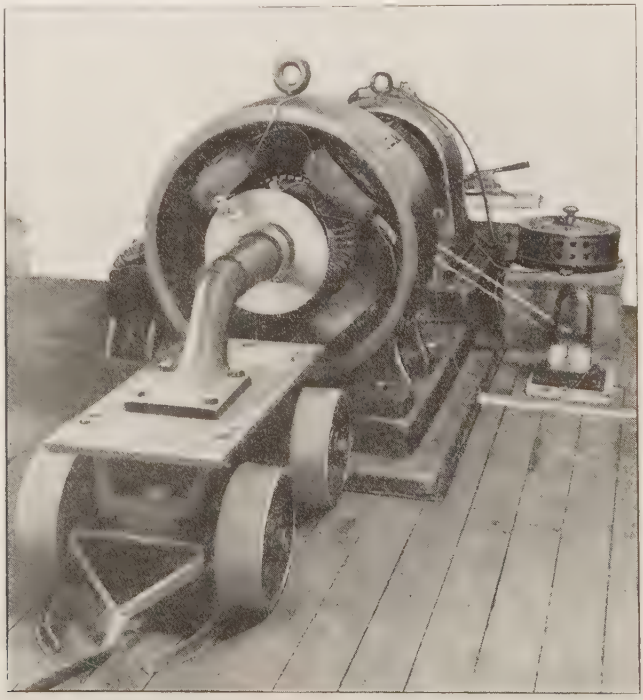


FIG. 1.—Sheet Steel Testing Device—Armature Method. Test Sample and Contact Device Shown in Position.

dynamometer used for reading the losses is shown in Fig. 2. The general plan of this apparatus is as follows:

A small variable speed, direct current motor has a shaft extension on which the sample is mounted. The speed is read in terms of voltage across the terminals of a small magneto which is belted

*Acknowledgment is made to the *Iron Trade Review* for the cuts used in this paper.

to the motor shaft and shown to the right in the photograph. The test sample is revolved in a field having specially wound field coils and adjustable pole pieces. The extension shaft on which the sample is mounted carries a spring dynamometer with a special device for reading the deflection on this dynamometer when the sample is in motion. The sleeve which carries the sample is provided with heavy flanges and is adapted to be placed in an hydraulic press, so that any desired degree of pressure may be reached and maintained on the sample during the test.

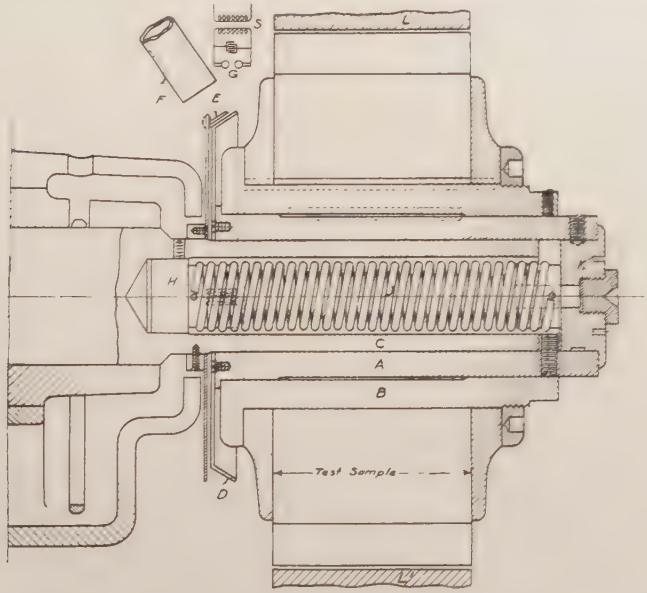


FIG. 2—Dynamometer for Measuring Armature Losses.

The very unique spring dynamometer used in this device was designed by Mr. S. M. Kintner and deserves special notice. As will be seen from the drawing (Fig. 2), the hollow shaft C contains a spiral spring J, the inner end H being rigidly held to the shaft, while the outer end is fastened to the sleeve A on which the sample is mounted. The shaft carries a pointer E and the sleeve a circular disc D approximately eight inches in diameter, graduated on its beveled face in a uniform scale to small divisions. In close proximity to the scale is placed a spark gap G, which is in series with the secondary of the induction coil S. The primary of the

induction coil is connected to a contact device on the motor shaft, the break point being exactly in line with the pointer E. Leyden jars are used across the secondary of the induction coil to cut down the duration of the spark. The scale and the pointer are shielded from the light of the room, and a tube F is provided for observing the scale and pointer at the exact angular position occupied when the spark passes across the air gap illuminating the scale and pointer for an instant at each revolution of the shaft. By this means it is perfectly feasible to read to a high degree of accuracy the deflection of the spring when the scale and pointer are both revolving at a speed of from 1,000 to 2,000 revolutions per minute. The bearing between the sleeve and shaft is nicely ground and well lubricated, so that there is practically no friction whatever when the test sample is in motion. The apparatus is calibrated by measuring the torque on the spring for an observed deflection. The loss in the sample is then measured in terms of torque and speed, reducing this, if necessary, to the ordinary units of watts per pound in the test sample. For comparative work this reduction is not necessary.

By varying the field strength, the air gap, the form of pole pieces, the speed and the pressure on the sample, tests under a wide range of conditions are obtained. The windage may be measured by taking readings on the dynamometer with no current in the field. In special tests, complete curves are taken at varying speeds and field currents. In routine tests only a few points are taken.

For convenience in handling the samples, which together with the sleeve weigh approximately 125 pounds, a special truck, shown in the foreground, Fig. 1, has been devised, by means of which the sample can be carried about and very quickly placed in position on the testing shaft with a minimum amount of labor.

The above apparatus is used for determining the quality of armature steel as received and the quality of the annealing. It forms a most convenient method of studying the variation in armature losses due to varying conditions, such as pressure, insulation between sheets, variation in induction, variation in form of armature slot, etc. The actual induction may be measured by means of a special coil slipped on the armature punching, the leads of which are brought out to a contact device mounted on the special

truck used for carrying the test samples. This device has been in constant use for several months and has been found so satisfactory that it may be confidently recommended to those desiring to make similar tests.

(c) TESTS FOR AGING.

It was discovered about ten years ago that when sheet steel is annealed so as to have a low loss and then subjected to a temperature of from 80° C. to 100° C., the loss sometimes increases, in some special cases this increase being as much as 100 per cent in ten days. Fortunately such cases are rare, and ordinarily the increase is small or there is no change whatever in the loss.

As the aging depends on the kind of material used and on the heat treatment to which it has been subjected, it becomes very desirable to make regular routine aging tests on all steel used for electrical purposes. This is all the more necessary as it is practically impossible to always get steel which has been subjected to identical treatments. These aging tests consist merely in repeating the measurements for total losses at certain definite periods of time after the initial tests, the sample being subjected in the interim to the aging temperature. Tests after ten days and after thirty days in the aging oven usually give the necessary data for judging the quality of the material. For purposes of investigation, longer tests are frequently necessary, especially when the effect of temperatures lower than the regular aging temperature is desired. In the tests with which the author is familiar, aging tests are frequently run for six months or a year, and some special tests have been in progress for approximately ten years.

The transformer samples are usually used for the aging tests on account of there being less material to handle and the tests being more easily made than with the armature samples.

The aging oven used for these tests consists of a large wooden box covered on the outside with galvanized iron and lined with asbestos. Steam coils are located at the bottom and ventilators are provided at the top and bottom so that a slight circulation of air may be secured to equalize the temperature. Steam at 150 to 180 pounds pressure is used for heating. The oven is divided into two parts, one of which runs normally at a temperature of very approximately 95° C. and the other at 60° C. to 65° C. These

temperatures are maintained year in and year out, and the oven

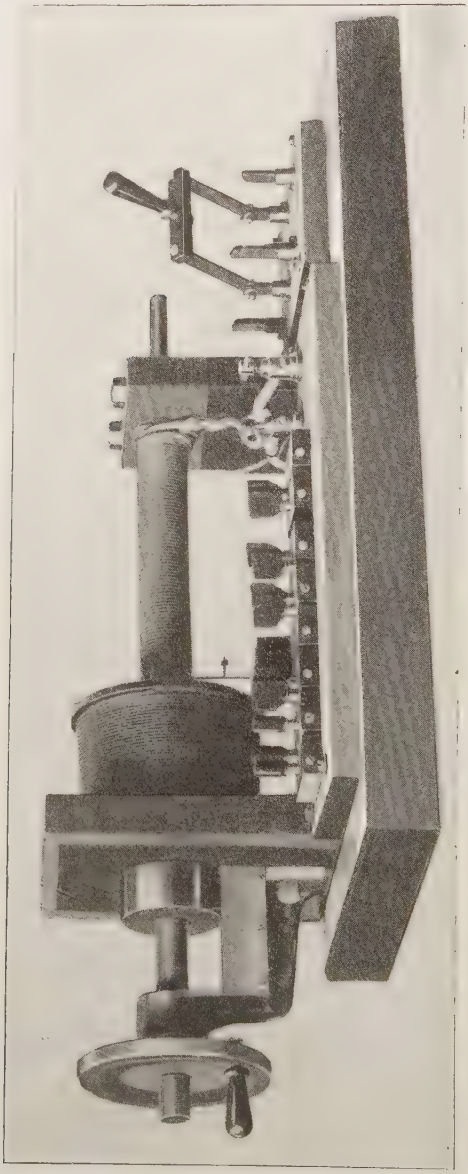


FIG. 3—Permeability Meter—Lamb & Walker Pattern.

usually contains from 100 to 200 samples which are undergoing the

aging test. The temperatures mentioned were selected for the reason that the higher temperature is comparatively easy to maintain and gives comparatively rapid aging when a material is found which is subject to aging, and the lower temperature represents very approximately the temperature at which ordinary electrical apparatus will run under normal working conditions.

(*d*) PERMEABILITY TESTS.

As stated earlier in this paper, the permeability of sheet steels used for electrical purposes varies over comparatively small limits, and the exact permeability of a particular sample is ordinarily not of great importance. It is not customary, therefore, to make routine tests for permeability. Occasional tests are advisable, however, and for this purpose a modified Permeability Meter, designed by Messrs. Lamb & Walker, and described in the Journal of the Institution of Electrical Engineers (London), Vol. 30, page 930, is generally used. This instrument arranged for measuring solid material in the form of round bars is shown in Fig. 3. For measuring sheet steel, the form of the coil and sample holders is changed so as to take rectangular sections. Strips of steel to be measured are sheared to the proper dimensions and clamped in blocks made for the purpose, the measurements being made exactly as in the case of solid material. With this instrument a complete permeability curve with hysteresis loop may be taken in a comparatively short time. The accuracy is not as great as with the well-known ballistic method, but it is sufficiently accurate for the purpose and the tests are much easier to make.

The intention of this paper has been to bring before the Society some methods of testing which are in daily use and which have been found very satisfactory for the purpose for which they are intended. They are not laboratory methods as the term is usually understood, but they are capable of giving valuable results from an investigation standpoint, as the results obtained may be applied directly to commercial apparatus. It is evident that any work that can be done to reduce the losses in electrical steel and prevent aging when the losses are reduced will be of great value to all manufacturers and users of electrical apparatus.

PERMEABILITY OF CAST STEEL.

By H. E. Diller.

It was formerly thought that pure iron was more permeable than any of the commercial steels, or any special alloy which could be made with iron. This assumption has lately been disputed and the claim put forth that the addition of silicon, phosphorus and aluminum to steel increases the permeability of the metal. However, at present it is the general rule among foundries making steel castings for dynamos and motors to try for about the following composition:—Silicon 0.10, Sulphur below 0.07, Phosphorus below 0.07, Manganese below 0.05, and Carbon below 0.10.

In order to find out more about the effect of small quantities of the different elements on the permeability of cast steel I got a set of bars, the first of which conformed to the above composition and each of the others varied from it in only one element. These bars were made with much care by the George H. Smith Steel Casting Company, of Milwaukee, who use the converter process. There were two bars in each set and the results reported are in all cases the average of two bars.

The values given are, I believe, absolute. They are at least relative. The bar and yoke method was used in making the permeability tests. The bars were one inch in diameter, and the mean magnetic path through the bar was 30 cm. long. The yoke was made of laminated steel, with a cross-section 4.5 in. square. The secondary coil of eight turns was right next to the middle of the bar, inside of the primary coil of 1500 turns. The constant of the galvanometer was taken with a standard solenoid, having a primary coil of 739 turns and 160 cm. long. Its secondary coil had 500 turns.

The reason for describing the method used for making these tests is that there is a great variation of results when compared to the curve of the Smith steel made by a Western university. These results differ so widely, especially at 10 H, that I

give them in the table. On the other hand my results on another cast steel checked within from 1 to 3 per cent of a curve made from that steel at an Eastern technical college. These variations would seem to indicate the advisability of not only a standard method, but if the bar and yoke method is used, a standard sized bar, yoke and standardizing solenoid. This Society could do a good work in formulating such standards.

The following is a table of the results obtained in terms of H and B to the square centimeter. The normal bar shows as good as any bar of commercial steel I have tested, so in comparing these results with those obtained by other methods it will be well to consider the normal bar as somewhat above the average dynamo steel. The analysis of the normal bar is:— Silicon 0.10, Sulphur 0.06, Phosphorus 0.06, Manganese traces, Carbon 0.09.

	10 H.		20 H.		40 H.		
	Unann d.	Annealed.	Unann'd.	Annealed.	Unann'd.	Annealed.	
College results of normal bar ..	13,600	.....	14,850	.....	15,760	.....	
Normal bar	11,310	11,650	14,670	14,870	16,160	16,200	
Carbon 0.32	8,750	9,550	12,050	12,730	14,440	14,860	
Carbon 0.43	7,580	8,620	11,880	12,730	14,440	14,870	
Manganese 0.43	10,810	11,580	14,080	14,690	15,710	16,100	B per sq. cm.
Manganese 0.65	10,280	11,270	13,590	14,440	15,460	15,960	
Manganese 0.95	9,660	10,700	13,020	14,040	15,170	15,730	
Silicon 0.43	10,960	11,710	14,160	14,760	15,920	16,150	
Silicon 0.54	11,590	11,890	14,220	14,550	15,660	15,900	
Phosphorus 0.17	11,330	11,910	14,190	14,630	15,660	15,950	
Phosphorus 0.27	11,860	12,010	14,460	14,690	15,620	15,920	
Aluminum 0.93 .	11,660	11,890	13,880	14,140	15,190	15,410	

The annealing increased the permeability in all the bars, especially in those containing a high percentage of carbon or of manganese, but the increase was much the greatest at the lower densities. The increase of B in the normal was only 3 per cent at 10 H and 1.3 per cent at 20 H. Probably in a heavier casting which would necessarily cool slower the annealing would have even less effect.

The carbon and manganese as might be supposed have a very harmful effect on the permeability, but .43 per cent of manganese lowered B of the annealed steel only 1 per cent.

This seems rather strange in view of the strong effect manganese has in lowering the permeability of cast iron.

Phosphorus, silicon and aluminum did increase the permeability but only to a small extent at 10 H, while at 20 H and at 40 H the normal bar has a higher permeability than any of the other bars. In this connection of an increase at the lower, and a decrease at the higher densities an experiment made with cast iron may be of interest.

A bar 17.75 in. long and 1.125 in. in diameter was heated and allowed to cool twelve (12) times, according to Mr. Outerbridge's recently published experiments. The bar increased to 18.25 in. in length and to 1.516 in. in diameter. The following are the B and H values.

	15 H.	30 H.	60 H.
Before annealing—B.....	3,480	5,670	6,640
After annealing—B	3,590	4,480	5,610

The results given from the steel bars would indicate that a substantial increase in permeability can not be gained by additions of silicon or aluminum unless they are added to the extent of several per cent, and even then it is doubtful whether there would be an increase in permeability above 20 H. Considerably more than 2 per cent of phosphorus would be required to affect the permeability to a marked degree. But at least it seems safe to remove the upper limits for these three elements in specifications for cast steel for dynamo work, so far as their effect on the permeability is concerned.

DISCUSSION.

THE PRESIDENT.—Mr. Skinner's paper is a fine illustration of the statement so often heard, that the money is made in the utilization of what used to be thrown away. I am sure we are all astonished to know the amount of the losses mentioned by Mr. Skinner. I hope you will discuss the paper. The President.

H. H. CAMPBELL.—The steel manufacturers are being constantly called upon to make steel with low electrical resistance, and this paper sheds a little light on the subject, but I think it can be expressed more clearly. I should like to see something showing the effect of phosphorus, manganese, sulphur and carbon. In a steel of great conductivity these four elements should be low, but it may be extremely important to get one low and it may be of slight importance about the other, and the ability to raise the limit of one of the elements might make a great difference in the cost of material, or even with the possibility of producing it at all. Mr. Campbell.

The castings that have been mentioned show 0.07 per cent. phosphorus and 0.07 per cent. sulphur. There is no necessity for such a large amount of phosphorus, and possibly the permeability would be increased by reducing the percentage. In the absence of definite information the steel makers are often unable to bid on work of this kind.

THE PRESIDENT.—If it is found that phosphorus is not detrimental in dynamo steel, and the questions of strength and brittleness are not serious, it would seem to be a very valuable point made, because of the well-known effect of phosphorus on the melting point. It will be much easier to get good castings with high phosphorus metal, than with low, on account of melting point. The President.

I should like to ask Mr. Skinner if he has any theory of the cause of the change which he has described as ageing.

C. E. SKINNER.—I have no working theory. The phenomena of ageing has been known and studied about twelve years. Ordinarily one does not think of a metal like steel changing its quality Mr. Skinner.

Mr. Skinner. at a temperature slightly below the boiling point of water, but changes of 100 per cent. in quality in ten days at this temperature have been recorded.

Mr. Kent. WM. KENT.—I should like to ask if the microscope shows any difference between the aged steel and the other?

Mr. Skinner. MR. SKINNER.—I have been unable to discover any difference, because the sample we have to use for the electrical test is so large in comparison with that for the microscopical test that it would require almost an infinite number of tests to make an absolute check. It must also be remembered that we are dealing with a steel of very low carbon, and slight changes are difficult to follow in such steel. A difference in appearance between steels having high and low initial losses can be seen in the microscope, but so far not the change due to ageing.

Mr. Stevenson. A. A. STEVENSON.—I know that a change does take place in certain steels if simply allowed to rest. We have found that in the case of tires, if they are allowed to rest for two weeks or more after they are made, and tests are then taken, there is a perceptible increase in percentage of elongation and reduction of area over tests made from the same tire within a day or two of its manufacture.

Mr. Metcalf. WM. METCALF.—I have had no experience in making this kind of steel, but it comes to me very distinctly that some ten or fifteen years ago, a friend of mine who was engaged very largely in the manufacture of sheet steel for electrical purposes, was in considerable trouble. I suggested to him, knowing about how the tests were running, that I thought he would find the physical condition of the steel was of more importance than the composition, and that if he would carefully make experiments with his steel as to the way he rolled it and the way it was heated, and send his samples out to the electrical company, he might probably find out the best physical condition, by which he could get the best results. He told me some months afterwards that he had followed that out largely, and that the physical condition of his sheets did have a great deal of influence, and he had improved his product very greatly to the relief of the electricians. It seems that all difficulties have not yet been overcome.

Mr. Lynch. T. D. LYNCH.—With reference to the strength of steel castings, Mr. Diller's paper impresses one with the idea that steel castings

used for electrical purposes do not require strength. I wish to suggest that in my experience I have found many cases where strength was required, and I was somewhat surprised at 0.10 per cent. being given as the proper carbon for steel castings. Mr. Lynch.

One case may be of interest to illustrate: A large casting intended for the revolving field of a high-speed generator showed on test about 60,000 pounds per sq. in. tensile strength, 30,000 pounds per sq. in. elastic limit, and 18 per cent. elongation in 2 inches. The carbon was about 0.20. All tests were hollow-drilled from the body of the casting. It might be of interest to add that this test could not be had at both top and bottom. Carbon 0.20 at the bottom may mean 0.35 at a point three feet above, due to the large mass and correspondingly slow cooling allowing segregations. From the electrical side it is desirable to have manganese under 0.50, and phosphorus and sulphur under 0.04. However, there seems to be no serious magnetic troubles so long as the carbon is kept under 0.50 and the manganese under 0.70. If either one is higher than these limits the other must be correspondingly lower. It seems to obtain, however, that when we get the proper high tensile strength and sound castings the electrical qualities follow. That is to say, we must have enough section to get strength and rigidity, and then the electrical conditions happily take care of themselves.

MR. SKINNER.—On account of the fact that in ordinary dynamo construction the reluctance of the air-gap is usually many times the reluctance of the remainder of the magnetic circuit, slight changes in permeability have comparatively little effect on the total reluctance of the magnetic circuit. Mr. Skinner.

It is also usually true that when sufficient amount of magnetic material is used, the physical strength is ample for the particular design. This may not be true of machines running at a very high speed.

As far as the sheet material is concerned, the combined hysteresis and eddy current losses form the chief consideration in the selection of material for a given design.

H. E. DILLER.—In regard to the tensile strength of steel castings for dynamo and motor frames, I would say that in medium and small frames it is not necessary to pay attention to it, as a cross-section large enough for the magnetic path will be amply Mr. Diller.

Mr. Diller. strong. In larger frames it is a matter of cost whether to use steel, semi-steel or cast iron, and one of the latter is usually preferred. Rigidity being the main requisite, a semi-steel will give the required results with a cross-section only slightly larger than when cast steel is used.

Mr. Kinkead. J. A. KINKEAD.—What is semi-steel?

Mr. Diller. MR. DILLER.—It is a cupola product in which we try to keep the combined carbon below 0.1 per cent., and the total carbon slightly below 2 per cent.

SPECIFICATIONS FOR AIR-BRAKE HOSE.

By Max H. Wickhorst.

Air brake and signal hose are items involving some little current expense to a railroad, the expenditures on the large railroad systems of the country running from $25,000 to $100,000 per year, and the matter is therefore of sufficient importance to deserve careful attention and close study. In 1898 an interesting and elaborate report on the subject of air brake hose was made to the Master Car Builders' Association, which report was the basis for the present M. C. B. standard specifications for air brake hose. These specifications call for a hose 3 or 4 ply, to be made of a good grade of rubber and canvas, canvas layers to be very strongly frictioned or cemented together and the inside rubber tube to have a very high stretch. About the same time the Burlington road desired to adopt specifications for air brake hose, and inspect shipments according to the specifications. It had been our experience and observation that the largest proportion of hose was rendered unfit for service due to external mechanical causes not having any necessary relation to the quality of the hose. The function of air brake hose is to safely and successfully retain air under pressure without allowing leakage. This requires that the inner tube be made of fairly good grade of rubber without serious imperfections of continuity, that the canvas layers hold together reasonably well and that there be sufficient material or number of ply to endure hard outside mechanical usage such as chafing, bruising, etc., without at once becoming too weak for safety. From our observations of the matter, the necessity was not clear of requiring such a high grade of rubber for the inner tube and for the friction layers between the canvas. Of course, other things equal, this very high grade of rubber would not be a disadvantage from the mechanical standpoint, but its effect is to very largely increase the price of hose, running from 25 to 40 per cent.

Relation of Laboratory Tests and Service Performance.—In order to get more definite and positive information on which to

base the specification, we determined to make some laboratory and service tests of several brands of air brake hose to determine, if possible, the relationship between ordinary laboratory tests and service performance. For this purpose twelve lengths, 22 inches each, of six different brands of air brake hose were obtained, and one length of each brand was retained to make laboratory tests to represent the original condition of the material. The other lengths were applied to suburban passenger cars, each length having a brass tag fastened to it, showing its individual number and the following marking: "Test Hose No. ———. Return to Laboratory, Aurora, Ill."

Samples were called in at intervals of six months and subjected to the regular laboratory tests. The laboratory tests were the usual ones, consisting of friction of canvas layers, stretch of inside rubber tube, permanent set taken by rubber, bursting pressure and observations concerning the condition of the hose. The friction of the hose was determined by taking a section of hose 1 inch wide, placing it on a roller $1\frac{1}{4}$ inches diameter and attaching a 25-pound weight to a loosened end of the canvas. The friction was the time it took for the weight to unwind a length of 12 inches. The apparatus used is shown in Fig. 1. The stretch of rubber was determined by measuring the length to which 1 inch of the inside tube 1 inch wide would stretch before breaking. The results recorded in this series of tests show this total length. This differs from the present method of making and expressing results of stretch in that at present a length of 2 inches is used, and the stretch is expressed in per cent. Fig. 2 shows the apparatus we at present use for making the determinations of stretch. The apparatus used in getting the results here recorded differed somewhat in construction, but carried out the same principle. The permanent set was deter-

FIG. 1.

mined by first stretching the rubber to nearly its maximum length, releasing, and then placing gauge marks 1 inch apart on it. The rubber was stretched to nearly its maximum length

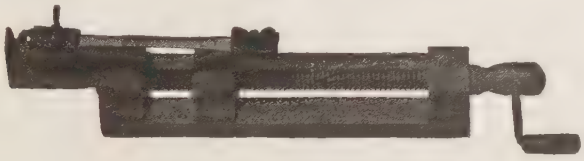


FIG. 2.

for ten minutes, released ten minutes, and the increase of length then measured, which is the figure recorded. The bursting pressure was determined in this series by means of water pressure, using a hand pump. The results obtained are shown in Table 1. The bursting pressure, friction and stretch in this table are plotted in Fig. 3. This table and the plotted results show some very interesting points, and I believe will merit close study. It will be noted that the brands tested range in friction from 1 second to 40 minutes in the original samples, range in stretch from $2\frac{1}{2}$ to 7 inches in the original samples, and range in bursting pressure from 650 to 825 pounds per square inch in the original samples.

The most striking point shown by the plotted results is that although some samples of hose had high initial friction, this friction dropped very quickly, and seems to bear no relationship whatever to the bursting pressure which the hose successfully maintains or the stretch of the rubber. These results seem to indicate conclusively that as good service may be expected from a hose having low friction and low stretch of rubber if the hose is substantially made, as from a hose giving high results in these two particulars.

BURLINGTON SPECIFICATIONS.

Having obtained results from these tests covering almost three years, the Burlington drew up specifications which were submitted to the various manufacturers for full criticisms and comments, and finally adopted their specification No. 15–A, dated October 1, 1902. This specification was afterwards slightly modified (although not to change the quality of the hose called for), as specification No.

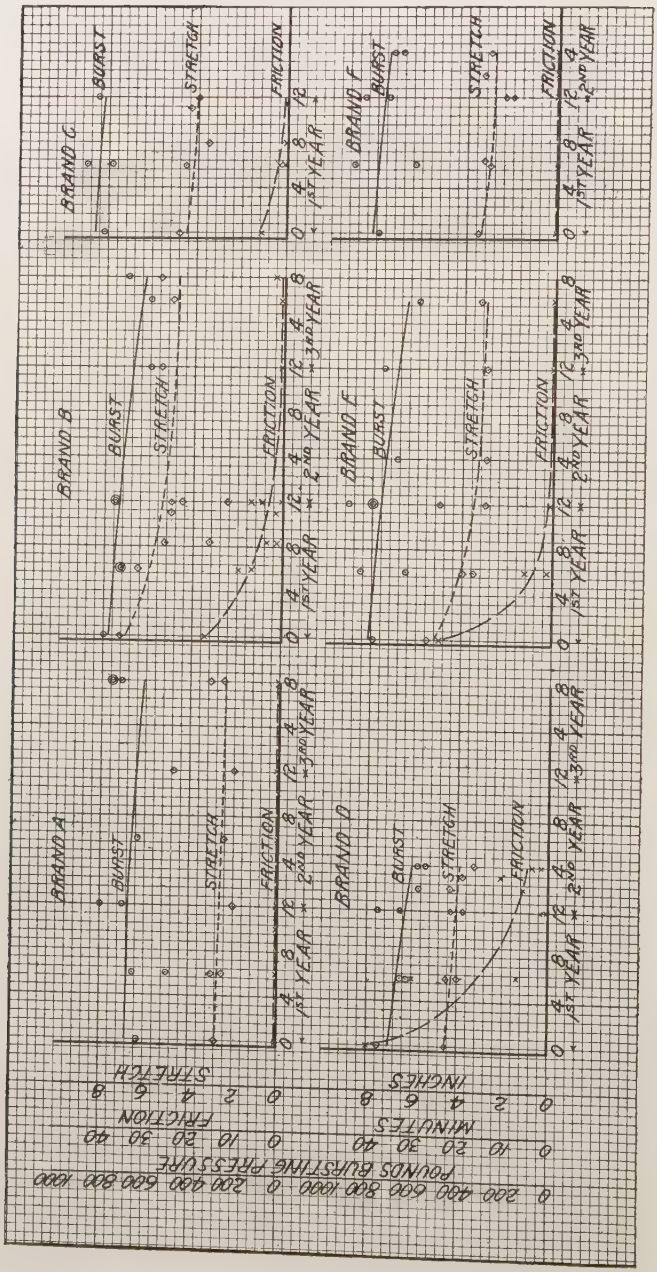


Fig. 3.—Bursting Pressure, Friction and Stretch of Air-Brake Hose.

AIR-BRA
LABORATORY TESTS AND

Brand A.

Service.	Hose No.	Friction.	Stretch.	Set.	Burst Lbs.	Remarks.
None.		1½″	2¾″	1/16″	625	
6 mo.	1	.6″	3″	1/32″	650	Removed for test. Somewhat chafed.
6 mo.	3	.8″	2.5″	1/32″	500	Removed for test.
10 m.	6	2″	None			Removed account leak near nipple
1 yr.	2	1″	2″	1/32″	800	Removed for test. Somewhat chafed.
1 yr.	4	1″	2″		700	Ditto.
1 y. 6 m.	5	2″	2.5″	1/32″	630	Ditto.
2 y.	7	1″	2″		475	Removed for test. Outer cover badly cut in one place.
2 y. 8 m.	9	.5″	2.5″	1/16″	750	Removed for test. Outer cover badly checked.
2 y. 8 m.	10	.5″	2.5″	1/16″	725	Ditto.
2 y. 8 m.	11	.5″	3″	1/16″	750	Ditto.

Brand D.

Service.	Hose No.	Friction.	Stretch.	Set.	Burst Lbs.	Remarks.
None.		40 m.	4.5″	3/32″	750	
6 m.	34	7 m.	4.5″	1/16″	625	Removed for test. Burst where chafed.
6 m.	35	30 m.	4″	1/16″	650	Ditto.
12 m.	38	1′ 30″	3.8″	5/32″		Badly chafed. Burst near nipple.
12 m.	36	35 s.	4.3″	1/16″	650	Removed for test. Slightly burnt.
12 m.	37	20 m.	2.5″	1/32″	750	Removed for test. Worn considerably and cut.
1 y. 2 m.	39	4′ 56″	4.3″	3/16″	470	Removed in shop. Badly chafed.
1 y. 3 m.	41	10′ 17″	3.8″	1/8″	45	Removed acct. badly chafed.
1 y. 4 m.	40	3′ 14″	3.3″	1/16″	575	Badly chafed.
1 y. 4 m.	42	1′ 17″	3.3″	1/8″	540	Chafed.

BRAN

Service.	Hose No.	Friction.	Stretch.	Set.	Burst Lbs.
None.		16.8 m.	7.3″	3/16″	80
6 mo.	12	10 m.	6.5″	1/8″	72
6 mo.	13	7 m.	6″	1/16″	72
8½ m.	15	1.3 m.	5.3″	3/16″	
8½ m.	18	3.5′	3.3″	1/8″	
11 m.	22	1′ 20″	5″	1/8″	
1 yr.	14	1 sec.	2.5″	1/32″	75
1 yr.	16	4.5 m.	5″	1/8″	75
1 y.	17	7 m.	4.5″	1/8″	30
2 y.	19	16 s.	5.5″	1/8″	60
2 y. 6 m.	20	42 s.	5″	1/4″	60
2 y. 8 m.	21	2′ 10″	5.5″	1/4″	70

BRAN

Service.	Hose No.	Friction.	Stretch.	Set.	Burst Lbs.
None.		25 m.	5.5″	3/32″	78
6 m.	45	6′ 30″	4″	1/32″	65
6 m.	47	1′ 15″	3.5″	1/32″	85
1 y.	46	2 s.	3″	1/32″	90
1 y.	48	29 s.	5″	1/32″	80
1 y.	55	3 s.	3″	1/16″	80
1 y. 4 m.	49	3 s.	3″	3/64″	69
2 y.	51	2 s.	3″	1/32″	75
2 y. 6 m.	52	2 s.	3.3″	1/32″	60

"Friction" is length of time to unwind a section of hose 1″ wide on a rolle
"Stretch" is length to which 1″ of the inside tube, 1″ wide, will stretch b
"Set" is taken after 1″ gauge length of inside tube is stretched 10 min. t
"Burst" refers to water pressure.

TABL

ATORY, AURORA, ILLINOIS

KE HOSE
SERVICE PERFORMANCE

LABORATORY No. 678, H 14
May 24, 1904

B.

BRAND C.

Remarks	Service.	Hose No.	Friction.	Stretch.	Set	Burst Lbs.	Remarks.
	None.		5.5 m.	4.8″	1/8″	820	
	6 mo.	23	1′ 15″	4.5″	3/32″	775	Removed for test.
	6 mo.	25	3 sec.	4.5″	1/16″	900	Ditto.
Removed acct. burst near nipple.	8 m.	26	30 s.	3.5″	1/16″		Worn due to rubbing on pilot of engine.
Removed acct. cut caused by wreck.	11 m.	31	19 s.	4.3″	1/8″		Badly chafed. Burst near nipple.
Hose torn acct. wreck.	1 yr.	24	20 m.	4″	1/16″	850	Removed for test. Fair condition.
Removed for test. Condition fair.							
Removed for test. Badly chafed.							
No record of removal. Badly chafed.							
Removed for test. Condition good.							
Ditto.							
Ditto.							

E.

BRAND F.

Removed for test. Burst where chafed.	None.		18 s.	3.5″	1/8″	790	
	6 m.	56	45 s.	3″	1/16″	900	Removed for test.
Removed for test.	6 m.	57	9 s.	3″	1/32″	625	Ditto.
Ditto.	6½ m.	61	5 s.	3.3″	3/32″		Removed acct. badly chafed.
Ditto.	1 y.	58	4.5 s.	2″	1/32″	750	Removed for test. Somewhat chafed.
Kinked.							
Badly chafed.	1 y.	59	10 s.	2.3″	1/32″	850	Removed for test. Badly scratched.
Removed for test. Somewhat chafed.	1 y. 2 m.	62	2 s.	3.3″	1/16″		Removed acct. chafed.
Removed for test. Burst where chafed.	1 y. 4 m.	64	13 s.	3″	1/16″	735	Ditto.
	1 y. 4 m.	66	22 s.	3″	1/32″	690	Slightly chafed.

1¼″ diam., with a 25-lb. weight, for a length of 12 inches.
fore breaking.
the maximum length it will safely stand and then released 10 minutes.

E I.

15–B, dated October 31, 1903, to which hose is now being bought. Copy of this specification follows:

CHICAGO, BURLINGTON & QUINCY RAILWAY COMPANY

SPECIFICATIONS FOR AIR BRAKE AND SIGNAL HOSE.

1. Air brake and signal hose must be four-ply and the inner tube not less than 3-32 inch thick. Each length must be 22 inches (variations of $\frac{1}{4}$ inch being allowed) and capped with rubber, vulcanized on each end. The wrapping must be frictioned on both sides and must have a distinct layer of rubber between each ply.

2. The inside diameter of air brake hose must be not less than $1\frac{1}{4}$ inches nor more than 1 5-16 inches, and shall have enlarged ends as follows: For a space of 3 inches from the ends, the internal diameter shall be not less than $1\frac{3}{8}$ inches nor more than 1 7-16 inches. The inside diameter of signal hose must be not less than 1 inch nor more than 1 1-16 inches, and shall have enlarged ends as follows: For a space of 3 inches from the ends the internal diameter shall be not less than 1 5-32 inches nor more than 1 7-32 inches.

3. Each standard length of hose must bear label like the one shown below. In the left-hand space must appear the month and year of manufacture, in the right-hand space the serial number and in the bottom space the manufacturer's name. The figures enclosed are for use in marking the date of application and removal. The figures must be not less than 3-16 inch in height and stand in relief not less than 1-32 inch, so as to be readily removed by cutting without endangering the cover tube.

BURLINGTON ROUTE.

(Month) (Year)									(Serial No.)
0 2 0 3 0 4 0 5 0 6	A	1 7	2 8	3 9	4 10	5 11	6 12		
	R	1 7	2 8	3 9	4 10	5 11	6 12		

(MAKER'S NAME.)

4. Air brake and signal hose will be ordered in lots of 200 or multiples thereof. Each lot of 200 must bear a manufacturer's serial number, commencing with 1 on the first of the year and continuing consecutively until the end of the year. For each lot of 200 hose ordered, 201 must be furnished. On receipt of a shipment one piece from each lot will be submitted to the following tests:

5. *Bursting Test.*—A section 3 inches long will be cut from one end of the test hose and the remaining 19 inches will be mounted on standard nipples and must stand an hydraulic pressure of 150 pounds per square inch, under which pressure it must not expand more than 3-16 inch in diameter, and subsequently of 500 pounds hydraulic pressure per square inch for ten minutes without bursting.

6. *Stretching Test.*—A section of the inner tube, 1 inch wide, will be stretched 300 per cent and then immediately released. Marks 2 inches apart will then be placed on it, the rubber stretched 300 per cent, or so the marks are 8 inches apart, held for ten minutes, then released for ten minutes and elongation noted. The rubber must stretch 300 per cent for ten minutes without breaking, and must not take a permanent elongation of more than $\frac{1}{4}$ inch.

7. Material failing these requirements will be rejected and disposed of as manufacturers may direct at their expense.

For comparison I also give below the present M. C. B. standard specification for air brake hose:

M. C. B. SPECIFICATIONS FOR AIR BRAKE HOSE.

In 1901 the following specifications and tests for an air brake hose were adopted as Recommended Practice. Advanced to Standard in 1903

1. All air brake hose must be soft and pliable and not less than three ply nor more than four ply. These must be made of rubber and cotton fabric, each of the best of its kind made for the purpose; no rubber substitutes or short fiber cotton to be used.

2. Tube must be hand made, composed of three calendars of 1-32 inch rubber. It must be free from holes and imperfections in general and must be so firmly united to the cotton fabric that it cannot be separated without breaking or splitting in two. The tube must be a high quality of rubber and must be of such composition as to successfully meet the requirements of the stretching test given below; the tube to be not less than 3-32 inch thick at any point.

3. The canvas or woven fabric used as wrapping for the hose to be made of long fiber cotton loosely woven and to weigh not less than 22 ounces per yard, and to be from 38 inches to 40 inches wide. The wrapping must be frictioned on both sides and must have in addition a distinct coating or layer of gum between each ply of wrapping. The canvas wrapping to be applied on the bias.

4. The cover must be of the same quality of gum as the tube and must not be less than 1-16 inch to $\frac{1}{8}$ inch.

5. Air brake hose to be furnished in 22-inch lengths. Variations exceeding $\frac{1}{4}$ inch in length will not be permitted. Hose must be capped on ends with not less than 1-16 inch or more than $\frac{1}{8}$ inch rubber caps. Caps must be vulcanized on, not pasted or cemented.

6. The inside diameter of all $1\frac{1}{4}$-inch air brake hose must not be less

than 1¼ inches or more than 1 5-16 inches, except at the ends, which are to be enlarged 3-16 inch for a distance of 2¾ inches, the change from the smaller to the larger to be made tapering.

The outside diameters must be kept within the following dimensions:

The main part of hose 1⅞ inches to 2 inches.

The enlarged ends 2 1-16 inches to 2 3-16 inches.

The hose must be finished smooth and regular in size as stated above.

7. Each standard length of hose must be branded with the name of the manufacturer, year and month when made, and serial number, the initials of the railway company, and also have a table of raised letters at least 3-16 inch high to show the date of application and removal, thus:

(LABEL.)

The above gives outline of modification of label. Extension being on right-hand end.

Each lot of 200 or less hose must bear the manufacturer's serial number, commencing at 1 on the first of the year and continuing consecutively until the end of the year.

For each lot of 200 or less one extra hose must be furnished free of cost for test.

All markings to be full and distinct and made on a thin layer of white or red rubber, vulcanized and so applied as to be removed either by cutting with a knife or sharp instrument.

8. Test hose will be subjected to the following test:

BURSTING TEST.

Test hose must stand for ten minutes a pressure of 500 pounds before bursting. Each hose must stand a shop test of 200 pounds.

FRICTION TEST.

A section 1 inch long will be taken from any part of the hose and the friction determined by the force and the time required to unwind the hose, the force to be applied at right angles to line of separation. With a weight of 25 pounds suspended from the separated end, the separation must be uniform and regular, and when unwinding, the average speed must not exceed 6 inches in ten minutes.

STRETCHING TEST.

A 1-inch section of the rubber tube or inner lining will be cut out at the lapped or thickest part. Marks 2 inches apart will be placed on the test piece; it will then be stretched until the marks are 10 inches apart, and released immediately. The piece will then be remarked as at first and stretched 10 inches, or 400 per cent, and will remain stretched for ten minutes. It will then be released and the distance measured between the marks ten minutes after the release. In no case must test piece show defective rubber or show a permanent set of more than ¼ inch between the 2-inch marks.

Small strips from the cover or friction will be subjected to the same tests.

9. If the test hose fails to meet the required tests, the lot from which they are taken may be rejected without further examination. If the test hose is satisfactory the entire lot will be examined and those complying with the requirements herein set forth will be accepted. All rejected hose will be returned to manufacturers, they paying freight charges both ways.

It will be noted that the Burlington specification differs materially from the M. C. B. in the following particulars:

First. We require no test for friction of canvas.

Second. Instead of calling for stretch of 400 per cent., we ask for only 300 per cent.

Third. We require four-ply, and do not allow three-ply hose. The bursting pressure is, however, about the same.

In order to fully meet the M. C. B. requirements, as stated in my introductory remarks, a much higher grade of rubber is required in the inner tube and between the canvas layers than the necessities of the case call for, resulting in an increase of cost to the railroad company from 25 to 40 per cent, with apparently but little if any increased service from the hose.

Statistics of Service Results.—The Burlington road has been buying hose to its own specification since January 1, 1903, and in order to have some fairly definite information as to the performance of specification hose, a record was started of all such hose removed from service. All hose removed from the C. B. & Q. R. R. Division of the Burlington System is shipped to the store at Aurora, Ill. When received here it is looked over by a laboratory inspector and record made of each length of hose on a card form 3 by 5 inches, as shown below:

AIR HOSE FAILURES.

		Class,
		Mos. Serv.,
Maker,	Date Made,	Serial No.
In serv.,	Out serv.,	Rec'd at Lab.,
A. B. or Sig.,		
Description of failure,		

Instructions adopted for making this record and tabulation of the results are as follows:

BURLINGTON ROUTE LABORATORY. AURORA, ILL.

AIR HOSE FAILURES.—METHODS OF KEEPING RECORDS AND TABULATING STATISTICS.

1. For each sample of failed air hose received at the Laboratory or Aurora Store fill out a printed card 3 by 5 inches provided for the purpose.

2. Hose failures should be classified as follows:

Due to External Causes:

A—Torn apart.
B—Chafed.
C—Cut.
D—Bruised at nipple end.
E—Bruised at coupling end.
F—Kinked.
G—Unclassified.

Due to Quality of Hose:

H—Defective inner tube.
I— " outer covering.
J— " wrapping.
K—Unclassified.

3. The cards should be classified in the file as follows:

First—By periods of time, *e. g.*, one year.
Second—By maker.
Third—By class of failure.
Fourth—By months service, using periods of two months. For example, a hose giving three months service should be classified as four months service.

4. At the end of each year or such period as may be desired the statistics should be tabulated on a tracing made for the purpose.

This record has been kept since October, 1903, and the results so far developed are shown in Table II:

TABLE II.

		Class of Failure.	Time in Service. 2 m.	4 m.	6 m.	8 m.	10 m.	1 y.	1 y. 2 m.	Total.	Per cent.	
External Causes.	A	Torn apart	9	11	12	6	4	....	....	42	8.35	Total, 464. Per cent, 92.25.
	B	Chafed	6	20	17	11	7	7	2	70	13.9	
	C	Cut	1	4	3	3	1	....	....	12	2.38	
	D	Bruised at nipple end	29	64	46	24	15	3	1	182	36.2	
	E	Bruised at coupling end	6	15	12	5	6	2	....	46	9.13	
	F	Kinked	1	8	31	21	15	3	....	79	15.7	
	G	Unclassified	8	10	5	4	4	2	....	33	6.55	
Quality of Hose.	H	Inner tube	....	....	....	....	....	....	....	....	.....	Total, 39. P.ct., 7.75
	I	Outer cover	....	3	9	14	6	2	....	34	6.75	
	J	Wrapping	....	....	1	1	....	....	....	2	.39	
	K	Unclassified	1	....	....	....	2	....	....	3	.59	
		Total	61	135	136	89	60	19	3	503	99.9	

This record is as yet too young to be entirely satisfactory, but it seems to show fairly clearly that the great bulk of hose is removed on account of being rendered unfit for service by external mechanical causes, apparently largely due to abuse by trainmen. For instance, failures due to Class A, "Torn Apart," are undoubtedly largely cases where the brakeman has failed to uncouple the hose. Failures due to Class D, "Bruised at Nipple End," show 36.2 per cent. These apparently are also cases where the brakeman fails to uncouple, or finds the angle-cock hard to turn and uses his heel or a piece of iron and accidentally hits the hose at the nipple end, bruising and weakening it at this point. Where hose fails due to material giving out, it is almost always due to unwrapping of the outer covers. This apparently would argue for high friction, but it will be noted that the percentage of failures from this cause is not great, and as shown above, even where hose has high initial friction, this quality is short-lived.

FRICTION OF HOSE.

In order to determine how long a sample of hose retains its friction when kept without being put into service, we retained samples in the laboratory as shipments were inspected, making determinations of friction, stretch of rubber and set of rubber at intervals of three months. The results of the determinations of friction are shown in Table III:

TABLE III.

FRICTION.

25 pounds unwinds 12″ in

SAMPLE.	Original.	3 months.	6 months.	9 months.	12 months.
1.....	40′	3′ 15″	17″	4″	11″
2.....	4 hrs.	4 hrs.	17′	11′	3′ 30″
3.....	15′ 45″	20″	10″	7″	7″
4.....	2 hrs.	25′	35″	15″	40″
5.....	7′ 30″	3″	2″	2″	
6.....	6′ 35″	1′ 20″	40″	12″	
7.....	11′	1′	40″		
8.....	13′	4′	40″		
9.....	3′	51″	26″		
10.....	45′	10′	7′ 30″		

From this it will be noted that all the samples show a loss of friction after three months; most of them losing almost all friction in six months, although in some cases the friction is retained somewhat more persistently.

In this connection it will probably be of interest to include some figures as to the amount of hose used per car per year, compiled by Mr. G. G. Yeomans, Purchasing Agent of the Burlington road. Mr. Yeomans first obtained figures from the purchasing agents of a number of roads whose climatic conditions were about the same as the Burlington, of the number of feet of hose bought exclusively for repairs covering a period of two years. He also obtained independently from the mechanical departments the average number of all classes of air brake equipment covering passenger cars, locomotives, freight cars, etc. From this he has figured the number of feet of hose used per car per annum for repairs. These roads were using different qualities of hose, and the results are shown in Table IV:

TABLE IV.

Road.	Price of Hose.	Feet per Car per Year.
Burlington	Medium	1.47
No. 1	Medium	1.51
No. 2	High priced	1.30
No. 3	Cheapest	3.35
No. 4	Part cheap—part medium	1.85
No. 5	Cheap	2.14

From the above table, it would seem that while hose cheap in price is dear in net results, on the other hand, hose high in price is likewise not the most economical.

DISCUSSION.

The President. THE PRESIDENT.—This specification is really a contribution. Everybody knows that hose is a single tube of rubber surrounded by alternate layers of ply and rubber. You will have noticed in the specification that adhesion is mentioned, and the question arises, what is the value of the adhesion? It will be evident that if the inner tube from any cause allows the air to pass through, the adhesion between the ply and the rubber becomes a most important element, since the adhesion is all there is to hold the air in. The tendency is for the air to work between the ply and the rubber next to it, going round and round, until it finally reaches the outside, and the hose is useless.

Mr. Smith. H. E. SMITH.—One thing that has impressed me in the hose specifications is that there is nothing, or very little at any rate, to show the durability of the rubber, except by inference, when it is new. This study of Mr. Wickhorst has shown what the actual facts are with old hose, but how shall we determine in advance what they will be with new hose? It seems to me that some test other than the stretching test might be desirable, and perhaps something like our accelerated tests for cements. In our laboratory we have tried a few experiments in the way of heating the hose and then making a second stretching test. It is too early to speak of any specifications in that line, but the results so far show that a good quality of hose after being heated in dry air for eight hours will still stand stretching test to six inches, and about the same effect is obtained by heating in steam for twenty-four hours. Possibly in the long run this particular test may prove to be worthless, but something to that end is needed.

Mr. Voorhees. S. S. VOORHEES.—Does experience in testing hose show that the reclaimed rubber will not stand the prescribed physical tests, especially the stretch and permanent set tests?

Mr. Bunnell. F. O. BUNNELL.—It has been my experience in making the stretching tests of rubber in which there is a considerable amount

of reclaimed rubber, that the elongation is considerably less and the permanent set considerably greater. Mr. Bunnell.

ROBERT JOB.—I noticed in Section 5 of the bursting test that 500 pounds hydraulic pressure per sq. in. for ten minutes without bursting is specified. Ordinary pressure on hose averages perhaps a hundred pounds to the square inch. I should like to ask whether it has been the general experience that this pressure test of 500 pounds is desirable, or whether, if 400 pounds is specified, we might not get a more pliable hose, and one which would stand more bending before final failure? Mr. Job.

The reason I raise this question is that in the course of our tests some of the manufacturers have claimed that by using hose made of somewhat lighter and coarser weave, better final results would be obtained, and that the hose made of looser weave of duck would be less liable to crack than that made of closer weave. The hose would be four-ply in either case.

W. C. DU COMB, JR.—I should like to ask Mr. Job about what ounce duck is used for air-brake hose. Mr. DuComb.

MR. JOB.—Twenty-two ounce. Mr. Job.

THE EFFECTS OF PRESERVATIVE TREATMENT ON THE STRENGTH OF TIMBER.

By F. A. Kummer.

In presenting these notes on the above subject, the writer feels that a certain measure of apology is due, for his failure to put the subject before you in the form originally intended. This failure arises from the inability to complete, prior to this meeting, a comprehensive series of tests upon the results of which the paper was to have been based.

It may be stated in advance, that the writer has for a number of years been engaged in the preservation of timber from decay, with especial reference to the production of wood paving blocks, possessing great durability under heavy traffic. The attempts made to successfully solve this problem have brought out some results which should be of interest to all users of timber.

There has been considerable confusion in the past as to the effects of different preservative treatments on the strength of timber, it being claimed that both the methods employed in preparing the timber for treatment, and the nature of the preservative employed, modify materially the strength of the wood. Little or no exact knowledge on this subject, however, has been secured, and it was in the hope of arriving at some results in this direction that the tests above mentioned were undertaken.

The work proposed consists of a series of tests made upon paving blocks, but in getting the necessary samples from the South they were unfortunately lost for a considerable period in shipment, and hence no results could be obtained which were sufficiently complete to place before you. The writer is, therefore, obliged to merely outline the nature of the work, in the hope that at a subsequent meeting, or possibly in time for the annual publication of the Society, the complete figures may be in shape for presentation.

The tests which the writer has under way are all being conducted upon long-leaf Georgia pine cubes, four inches square. In the first place these cubes have all been taken from timber as

nearly identical in weight and general characteristics as possible, coming largely from the same logs, these logs being selected so that only butt timber is used. All this timber has been bled. Only butt timber was selected because of the well-known variation in the strength of timber depending on whether it is taken from the butt or the top of the tree. The tests comprise, first, tests as to the absorption of moisture—this being determined by carefully drying the timber for a period of 24 hours at a moderate temperature of 110° F. and then immersing in fresh water at 70° for a period of 24 hours. The second line of tests was first intended to be for crushing, but it was at once realized that tests of this nature result in the rupture of the entire block, this rupture depending largely upon the physical condition of each individual block and not representing anything like the actual conditions met with in practice, where each block is firmly supported by those surrounding it; it was, therefore, determined to make a cubical box with adjustable sides in which each specimen could be firmly held during the test, and instead of subjecting these specimens to crushing, to force into them along the line of the fiber a die of 1 square inch in area for a distance of $\frac{1}{4}$ of an inch. The die is so arranged with a proper shoulder that it is forced into the timber exactly $\frac{1}{4}$ of an inch in the case of each specimen, so that readings of the number of thousand pounds required to effect this penetration in each case would give fairly good comparative results. Is is not of course claimed that this method of testing reproduces in any way actual conditions, but in the opinion of the writer such results should show with a considerable degree of accuracy the relative value of the various blocks.

In conducting these tests the idea is to start with 100 identical blocks. Ten of these would first be tested as follows: five for absorption of moisture, and then all ten as just described above. It will thus be seen that the results secured would be not only the absorption of moisture and the penetration of the die, under pressure, but also the penetration of the die upon blocks which had absorbed moisture, it being proposed to conduct the tests with the die immediately after the absorption tests.

After carrying out this program on the ten samples just as cut from the log it was then proposed to take a second ten and from these extract, so far as possible, all of the moisture, sap, volatile

oils and resin, this being done by a somewhat different method than that usually employed in treating timber, which method utilizes somewhat higher temperatures, and removes a much higher percentage of these materials from the wood. In fact the temperatures used are so high that the question has been raised as to whether or not the heat used injured the fiber of the wood for paving-block purposes.

It will thus be seen that the tests upon the second lot of ten blocks would show, as in the case of the first lot, the absorption of moisture, the resistance to the entrance of the die, and the resistance to such entrance after this wood, relieved of all of its resinous material, had been allowed to absorb moisture for 24 hours. In this connection it may be stated that tests by the Bureau of Forestry have shown a difference of almost 100 per cent between the cross-breaking strength of timber full of moisture and of timber completely freed from the same. It will readily be perceived that the absorption of moisture by paving blocks has a very direct effect upon the durability of such blocks. The usual specification for blocks of this character to-day calls for an absorption, after 24 hours' immersion, of not to exceed 3 per cent.

The third lot of ten blocks will then be tested after treatment with dead oil of coal tar, the treatment being carried to completion, so that all parts of the block are thoroughly saturated, which requires about 22 pounds of material to the cubic foot of wood. The preparatory treatment of these blocks is the same as that used on lot No. 2, in fact the tests are carried forward progressively from the start. Tests on this lot will show to what extent thoroughly creosoted wood will absorb water, and to what extent, if any, the fiber of the wood is softened either by the oil or by the nature of the preparatory treatment.

Without taking up much more of your time, it will suffice to say that a fourth lot of blocks will be similarly tested after being thoroughly treated, with a creo-resinate mixture composed of equal parts of dead oil and melted resin. It is believed that the incorporation of the resin with the oil greatly increases the waterproof qualities of the wood and, by solidifying in the cells, makes the wood harder and denser, and therefore better able to withstand abrasion or crushing. Incidentally it is also supposed to prevent the evaporation of the volatile parts of the creosote oil.

Other series of tests will be conducted on blocks treated with varying percentages of creosote oil and resin, and will also probably include tests on blocks treated with resin alone, as well as tests on blocks treated by that modification of the creosoting process known as the Ruping process, which has just been introduced into this country from Germany, and in which the writer is informed the Atchison, Topeka and Santa Fe Railroad is taking a great interest. This process, in a few words, consists, first, in filling the pores of the wood with creosote oil and then removing from 70 to 80 per cent of it, it being claimed that only so much oil is necessary in the timber for efficient preservation as is necessary to coat the cell walls.

The writer fearing that under these circumstances the oil would be removed from the timber by the action of air and moisture, it is also proposed to make tests upon blocks and also cross-breaking tests upon cross arms, which, after being treated in this manner, are given a surface treatment of pure resin, sealing up the pores for say a distance of $\frac{1}{2}$ inch and effectually preventing the entrance of moisture and air. It is not claimed by its owners that the Ruping modification is valuable for paving blocks, but it affords a very cheap method of treating railroad ties if satisfactory. It is the opinion of the writer that for this work the surface coating of resin would be of value not only in retaining the extremely diffused body of oil in the wood and preventing the admission of air and moisture, but also, by very materially hardening the surface of the timber, reduce the danger of rail cutting.

The writer is far more interested in the question of specifications and methods for producing paving blocks of extreme permanence and durability, than in the question of railroad ties, but in his opinion, the great solution of the problem of the treatment of timber, and more particularly of yellow pine timber, lies in the possibility, not of cheapening the process employed, so much as in the possibility of reclaiming from the wood, during the preparatory treatment, products of such value that the whole cost of the entire operation is thereby materially reduced.

Mr. Page, at the meeting of the Committee on Standard Tests for Road Materials, also suggested to the writer the making of abrasion tests with the Doré machine, now being tried in Washington, for which tests the writer has arranged to supply samples.

The subject of this paper is a very broad one, too broad, in fact, to be treated in any one paper, or by any one series of investigations. It would extend to all kinds of timber, for a wide variety of uses, and to all kinds of preservative treatments. The writer has for the present confined his investigations principally to one commercial form of Georgia pine, namely, paving blocks. To many of you whose lines of work do not extend to street paving, the knowledge that wood pavements have become standard pavements for heavily traveled streets, and that their manufacture and use comprises a large business, will perhaps come as somewhat of a surprise,—yet such is the case, the pavement having been specified for such notable structures as the Williamsburg and Blackwell's Island bridges between New York and Brooklyn, and used in large quantities on heavily traveled business streets in most of our larger cities to-day. New York City is at this writing asking for bids on over $100,000 worth of such pavements, while even smaller cities, such as Minneapolis, Minn., ask for bids on such large quantities as 50,000 square yards at one time. This, of course, refers to carefully constructed pavements of well-treated blocks on concrete foundations, costing in many cases double as much as asphalt. The writer mentions these facts for the purpose of emphasizing the fact that tests and investigations of this form of pavement are daily becoming more necessary not only for the benefit of the consumer but for the producer as well.

RESULTS OF AN INVESTIGATION OF CERTAIN STRUCTURAL PAINTS.

By Robert Job.

In a paper read before the Franklin Institute last February and to appear in the July issue of the Journal of the Institute we gave the details of an investigation to determine the causes of differences in durability of three standard bridge paints used upon the lines of the Philadelphia and Reading Railway for over ten years.

Each of the three paints consisted of about 22 per cent sesquioxide of iron with about 78 per cent of an inert base of clay and of varying proportions of hydrated sulphate of lime, the pigment being ground in paste form in pure raw linseed oil and thinned for use with raw linseed oil and a little standard japan. One of the paints, No. 12, gave excellent service, while another, No. 8, had only about half the life of No. 12 under identically the same conditions.

As a result of the investigation it was found that the essential difference lay in the relative fineness of the pigments,—in No. 12 the particles were exceedingly minute, whereas in No. 8 they were comparatively coarse. The former contained 10 per cent hydrated sulphate of lime, and the latter 64 per cent.

We also worked out a method by which the difference in fineness could be readily detected, and shipments held to the quality of the No. 12 paint, our method being to mix four parts by weight of the paste with ten parts by weight of pure raw linseed oil, place a few drops upon a clean, dry glass slip, and stand vertically at a temperature of 100° F. for one hour. Under these conditions there should be no separation of pigment from oil, no material fading from the original shade, and no feeling of grittiness under the spatula.

The No. 12 paint passed this test readily, while the No. 8 paint showed a very marked separation of pigment from oil and an almost complete fading of color upon the glass after the test. In other words, the pigment in the No. 8 had largely dragged down from the glass, leaving little more than a film of oil.

These results naturally led to a study of the different pigments and paint materials which could be used to best advantage in building up a paint having the properties found in the No. 12 paint, and during the past six months we have devoted a considerable amount of time to further study of these pigments. The results which have been obtained have proved very clearly that it is a matter of extreme difficulty for the manufacturers to take a relatively coarse pigment of the desired composition (*e. g.*, 25 per cent sesquioxide of iron and 75 per cent of inert material) and attempt to bring it by milling after mixing with oil to the degree of fineness specified above.

As a case in point we may cite a paint made up of ochre with a considerable proportion of sulphate of lime in paste form with raw linseed oil. With such pigment our experience has been that even repeated grindings in the mill will not suffice to reduce to the degree of fineness necessary to ensure efficient service, the reason being, apparently, that sulphate of lime is naturally of a granular character, and when grinding with oil is attempted, the viscosity of the oil is sufficient to keep the stones from coming into close contact, and as a consequence, but little actual reduction in size of the particles of pigment results after a given degree of fineness has been obtained. Therefore repeated milling of such material merely adds to the cost of production, and causes little improvement in quality. As stated by Dr. Dudley in the discussion of the above paper, pigments can be made fine in the dry condition (*i. e.*, without oil) much cheaper than after mixing with oil, and our experience has been that very much the best results can be secured by use of a very finely floated paper clay as the inert material, for the reason that the particles of such material are very minute,—very much finer than can be secured with a coarse pigment by the most rigorous milling with oil,—and in building up our iron paints we prefer to have the largest possible proportion of such base, or of other inert pigment made equally fine by floating, or by milling before addition of oil,—if so desired. We have also found that excellent fineness is commercially obtained in dry pigments high in sesquioxide of iron contents, and some such pigments will pass our fineness test when merely mixed with the proper proportion of raw linseed oil without any milling, and we have also found that an iron pigment which is relatively low in

iron and which contains any considerable proportion of free silica is exceedingly difficult to get into proper condition of fineness unless by floating or perhaps by dry grinding, the cause evidently being due to the well-known difficulty of fine grinding of silica owing to its hardness.

Our advice, then, in the manufacture of these inert paints is to use enough finely ground iron pigment relatively high in sesquioxide of iron, to give the desired color and good covering properties, say a total of 25 per cent sesquioxide of iron, and to have the remainder of the pigment composed as largely as possible of the finest floated paper clay. Such a combination, if properly ground with raw linseed oil in paste form and thinned for use with raw linseed oil with addition of a little japan of good quality, gives, according to the teaching of our service results, a high efficiency in protection of structural work, combined with relatively low cost of material.

DISCUSSION.

The President. THE PRESIDENT.—In regard to the test for fine grinding mentioned by Mr. Job, we have found in our experience that a little water mixed with the paint makes the greatest possible difference whether the material stands test or not. Hundreds of shipments have been tested in our laboratory which would not stand test as received, but which would stand test if a single drop of water was mixed with the paint and rubbed up with it. Accordingly we have modified the test for fine grinding, and now test by separating the pigment from the oil, drying it thoroughly, and then mixing it with oil in the proper proportions, which oil has also been deprived of its moisture. In this way the test is absolutely reliable, if we can trust our experience.

Mr. Job. ROBERT JOB.—In making these tests I separated the pigments and mixed them with pure raw linseed oil in proportions of three parts by weight of the pigment to eleven parts by weight of the oil, which proportions correspond to four parts by weight of the paint in paste form to ten parts by weight of oil. In making this test it is well to add the oil before the gasoline has been entirely evaporated, in separating the pigment from the oil, in order to prevent drying of the pigment in hard lumps which are difficult to break up with the oil.

The presence of water in the paint does not aid the material to pass the test since at the temperature of 100° F. the water quickly evaporates.

Mr. Thompson. G. W. THOMPSON.—I should like to ask Mr. Job a few questions, if I may be permitted, in regard to his tests. He makes no mention in his paper of the amount of pigment present in either of the paints referred to. This, it seems to me, is a very important thing. Of course, if you have a coarse pigment and a fine pigment, and these pigments are mixed in the same proportion in the vehicle, the coarse pigment would tend to fall out of the vehicle; and yet, on the other hand, if the relatively coarse pigment were mixed with less vehicle, it might be applied and have entirely different protective qualities from what it would have if it were mixed with

more vehicle. Mr. Job refers to tests, using three grains of pigment and eleven grains of oil. Of course, while this is all right as a test for fineness, yet it proves nothing directly as to the protective character of the pigment, because when he comes to paint with it, the practical painter will probably mix that paint in the proportion suitable for application. He will put more vehicle with the fine than with the coarse pigment, and therefore the percentage of pigment comes in question again. Mr. Job has said nothing about the conditions to which the paint is exposed, except that he mentions that they were exposed to the same conditions. I think it would be instructive for him to state the conditions to which they were exposed. With respect to this test for fineness: We know that there is a great deal yet to be learned about linseed as a protective coating and paints generally, and there are lots of things in linseed oil which paint grinders find themselves up against continually. There is such a thing in grinding as what they call surface tension, which cannot be explained. Grinders may have two oils that, as far as they can see, are chemically identical; yet, one will mix with a batch of pigment taking seventeen gallons, and the other oil will mix with a batch of that same pigment in the proportion of twelve, thirteen or fourteen gallons. I simply mention this as an illustration. It might possibly have some bearing on Mr. Job's tests, because the pigment itself may change the surface tension of the oil and the coherence of its particles. Mr. Thompson.

I should like to add a word or two more, but I think perhaps if Mr. Job will reply to these inquiries at this time it will be of interest.

ROBERT JOB.—As regards the percentage of oil in these paints I can state that both paints contained closely the same proportions. Also, in mixing the paint paste for service, the same batch formula generally was used. Under these conditions the No. 12 paint was slightly thicker than the No. 8, and consequently the No. 12 paint contained a slightly greater proportion of pigment than the No. 8 paint. Mr. Job

So far as the conditions of application are concerned, the paints were applied to our bridges, both steel and wood, all over our lines for a period of about ten years. That means, of course, that we had practically every kind of exposure and conditions that can be imagined.

Mr. Job. No. 8 was of a reddish color, and the main body of the bridge was painted with it. No. 12 was of a green color, and was used as a trimming color on different parts of the same bridge. The two were used all through the structures in all sorts of different locations, and were thus brought into as intimate relations as could be possible. Also, we found the relative service values all through the different structures. In the case of No. 12 paint there were generally good results, and with the No. 8 poor results, right side by side on the same bridge.

As far as the matter of surface tension is concerned I cannot say anything. I do not know exactly what the effect would be.

Mr. Thompson. MR. THOMPSON.—In reference to the fineness test, while it would work with paints peculiarly known as inert pigments, it would not work with red lead, because that contains some litharge. This question of fineness is an exceedingly important one. It seems to me that the physical character of a pigment and its fineness have more to do with its qualities than does composition.

I derived much benefit and instruction from a series of articles which Dr. Dudley wrote and published in the *Railroad Magazine* twelve or thirteen years ago. If I remember correctly, one of his points was that the pigment protects the oil. He furthermore advanced the proposition that the greater the percentage of pigment, within certain limits, the greater the protection of the paint. Now, however, we are told that the finer the pigment the greater the protection. But the finer the pigment, the less pigment you can put in your paint, and the coarser, the more you can put in it. Consequently, if we say that the finer the pigment the greater its protective quality, we must add these words, it seems to me, "consistent with proper application, proper covering, and proper working qualities." We can go too far in the fineness of the pigment. That is the case with zinc. It is so fine that we cannot use it by itself, but by putting a comparatively coarse pigment with it it can be used. Consequently, the statement that the finer the pigment the greater the protection should be qualified.

Slowness of drying is an advantage, in that the drying of paint is in itself a destructive operation. Dryers are destructive agents, and the less dryer you put in, the less the destructive agency, and the slower the drying, the slower the decomposition of the paint will be.

PRESERVATIVE COATINGS FOR IRON AND STEEL.

By Cyril de Wyrall.

The most essential point to be considered in specifying preservative coatings for iron and steel is the fact that different conditions require different treatment. The coating, which is efficient where the steel is exposed to pure air and sun, will not answer in such places as train sheds or subways; and vice versa. I do not believe that any coating has yet been found that will withstand the action of two opposite sets of elements, such as will be found in the open air, on the one hand, and in a subway, on the other: as well expect asbestos to withstand water as effectively as fire.

I had charge of the time-tests of the different materials submitted for the New York Rapid Transit Subway, and, while I know that several were good preservatives for steel above ground, all of them were dismal failures as preservatives in the subway. Nearly all of them had as a vehicle linseed, or some other vegetable oil, which in a short time saponified owing to the action of the atmosphere, and rendered the pigment worthless as a coating. The same thing will apply to a train shed in a greater degree. I have taken strips of paint from 10 to 16 inches long and 3 inches wide from columns, in single pieces, the paint on the surface being apparently sound, and the under surface, that next to the steel, having a rust scale of from 1-32 to $\frac{1}{8}$ inch thick. These columns were sandblasted in the field, then coated with red lead and linseed oil. After erection they were cleaned and scraped with steel scrapers, then thoroughly brushed with wire brushes, coated again with red lead and linseed oil, and finally with a coat of white lead and linseed oil. All of the ingredients were analyzed before being used, yet with all these precautions the conditions above mentioned developed in less than a year and a half. In this respect the value of a chemical analysis is nil, that is, to determine the efficiency of a coating; nor can any comparative

chemical test be made that will give any definite idea of what different coatings will do under actual conditions, because no such test contains all the elements that unite to destroy the efficacy of the coating.

A careful study of the causes of the failure to preserve, of the different "preservatives," led to the adoption of a paint in which a bi-product of petroleum was used as a vehicle, this being the only one to stand the test successfully. For enclosed steel, or for steel exposed, under cover, to dampness and foul air, away from the action of the sun, I do not think that a better preservative has yet been found than that in which a vehicle of a petroleum nature is used, for the reason that it will not saponify; nor does it dry hard except on the surface. Such a vehicle is practically worthless by itself for open-air work, as the action of the sun seems to disintegrate it; but mixed in certain proportions with other oils it makes a fairly good preservative coating for above-ground work.

Where the color is not objectionable, I have found that a paint made of the tar residuum of petroleum mixed with some of the lighter oils (petroleum products) is the best preservative for train-shed steel. It is impervious to the action of the gases caused by locomotives, one of the most destructive enemies of paint. And what impressed me very forcibly, was the fact that where there was an abrasion of the paint and the exposed piece of steel was rusted, the rust did not extend any further than the exact line of the abrasion, a circumstance not found in the general run of preservatives.

The pigment used, provided it is inert, makes but little difference. I have found equally good results from using a good oxide of iron in one case; a mixture composed of white lead 30 per cent, yellow ochre 25 per cent, barytes 40 per cent, lampblack 5 per cent in another case; and venetian red 60 per cent, yellow ochre 30 per cent, lampblack 10 per cent, in another case, using the same vehicle. After two years trial I fail to find any material difference in the preservative qualities of either. While the coatings mixed with linseed, or other vegetable oils, after being exposed less than a year, became dry and porous, allowing the moisture accruing from condensation to reach the steel and thus cause corrosion, the coatings mixed with the petroleum product were full of life and tenacity, and the steel underneath was in excellent condition.

I am of the opinion that the best preservative for steel is a coating that is slow in drying and that does not become thoroughly hard, because a coating cannot become hard unless brittle, and thus will be more apt to crack and scale off. I repeat, however, that different conditions require different preservatives, and it behooves paint-makers to give more attention to the vehicle rather than to the pigment, for that undoubtedly is the life of the coating. Resinous gums such as are used in varnish-making are as a rule detrimental when mixed with linseed oil, the one having a tendency to set quickly and dry hard and the other to set slowly and keep elastic. This accounts in a great measure for the cracking and peeling of a number of coatings for steel. It is very important, too, no matter what coating be used, that it should be brushed out to a thin, even surface. Two thin coats are in every way preferable to one heavy coat, for if paint be applied at all heavy on steel or iron it will shrivel up and peel off in a short time. I have made a number of service, or time-tests, with coatings applied both thin and thick, and in every case the thin coatings outlasted the thick ones, in the ratio of two to three.

SOME STATISTICS OF THE CEMENT INDUSTRY IN AMERICA.

By R. W. Lesley.

I have been asked to give you in very brief form a few figures on the growth of the American Portland Cement Industry, with which I have been connected for many years. Of course, much of what I have to say is ancient history, because it is only ancient history from which diagrams can be made, and as the principal part of what I have to say to you to-day consists of diagrams, you can understand that ancient history is the essential part of my discourse.

The American Portland Cement Industry is one of the remarkable developments of the past twenty years; in fact, it might almost be said, of the past ten years. The words "Cement" and "Concrete" to-day seem to the engineer almost as familiar as iron and stone, so far as construction is concerned, and the engineering papers are filled with articles of the most interesting character, describing the various forms of concrete and reinforced concrete construction, and yet it is quite within the knowledge of the writer in his early cement days that to find a single paragraph in the scientific papers of this country, or even of England, referring to this subject, was the occasion of more or less rejoicing.

When we talk of the consumption of an article, the use of an article and the growth of an industry, we may generally find that along parallel lines will be the growth of the literature of the subject. This is one of the interesting developments of the growth of the industry to those who have been for years connected with it.

In speaking of this subject I want to call your attention to a diagram showing by the comparative height of a cement barrel, the growth of the American Portland Cement Industry. These figures speak for themselves, and if the table were brought up to the present period by adding the year 1903, for which values are

soon to be published, the results would be even more remarkable. These barrels pictorially tell the tale of the development of the industry, and emphasize more than words could, what American manufacturers have been doing.

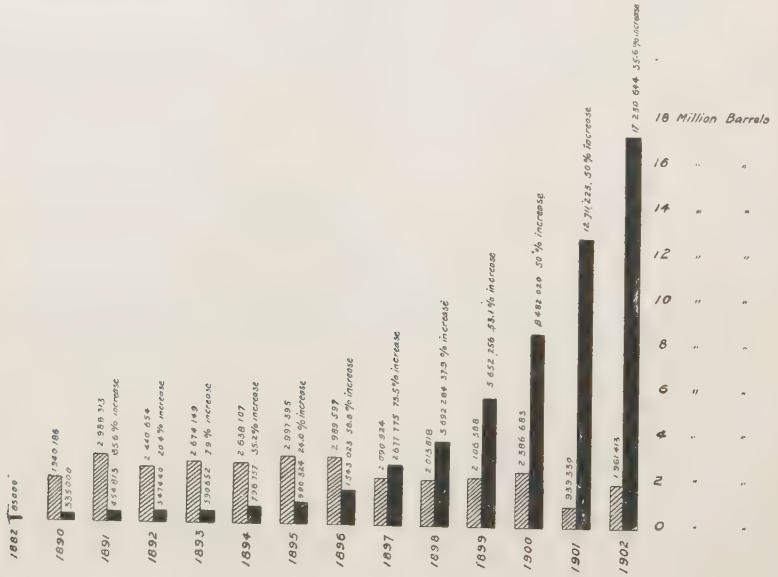
It will be remembered that in the seventies practically all the Portland cement consumed in the United States came from abroad, and that foreign cement, especially the German and English brands, had a reputation which it was difficult to overcome and commanded the market for all large work. The difficulties of the establishment of American Portland cement have been told in other papers by the writer, and it is needless to repeat them

THE GROWTH OF THE AMERICAN PORTLAND CEMENT INDUSTRY AS SHOWN BY THE COMPARATIVE HEIGHT OF A CEMENT BARREL.

here; but the diagram which follows shows for the past twenty years the relation of the American production to the imports of foreign cement, and how gradually American production has overtaken importation, until the latter bears but a small percentage to the enormous consumption of Portland cement in this country. This table shows the domestic production and imports of Portland cement from 1882 to 1902.

At the beginning of this period we made 17,000 tons of Portland cement and about a million tons of natural cement, and imported about 74,000 tons of Portland cement. Until 1897 the production of American Portland cements was much less than the foreign importations, but in that year it forged ahead rapidly. This growth was due to a number of causes, of which an important

one was the sudden realization by engineers that there was nothing to prevent the manufacture of good Portland cement in this country except their refusal to buy it. About that time specifications were recast so as to accept material made in this country which was of satisfactory character. When users of cement found how easily their requirements were met by American producers, they began to call for finer grinding than before, higher tensile strengths and other properties. These specifications improved the quality of



NOTE.—Hatched lines represent imports; solid lines represent domestic production.

COMPARATIVE DIAGRAM SHOWING DOMESTIC PRODUCTION AND IMPORTS OF PORTLAND CEMENT.

the American product until to-day it is the equal of that of any country. Under such conditions it is not surprising that the foreign imports have fallen off materially of late.

Portland cement, however, is not the only cement that this country produces, because since the early days of canals, the United States has been one of the great producers of natural cement, and much important work has been done for years with such good cements as those made in the Cumberland, Lehigh,

Louisville and Milwaukee cement districts. These were the first cement works of the country, and an examination of the Census Report for 1850 shows there were 35 cement works in the United States, all making natural cement, and having a daily capacity of 14,500 barrels.

The following table shows the relation of natural and Portland cement to each other in this country, and the remarkable growth in the annual output per individual cement plant, as compared with the early figures of 1850:

PRODUCTION AND CONSUMPTION OF NATURAL AND PORTLAND CEMENT IN THE UNITED STATES; AND AVERAGE PRODUCTIVE CAPACITY OF AMERICAN CEMENT MILLS.

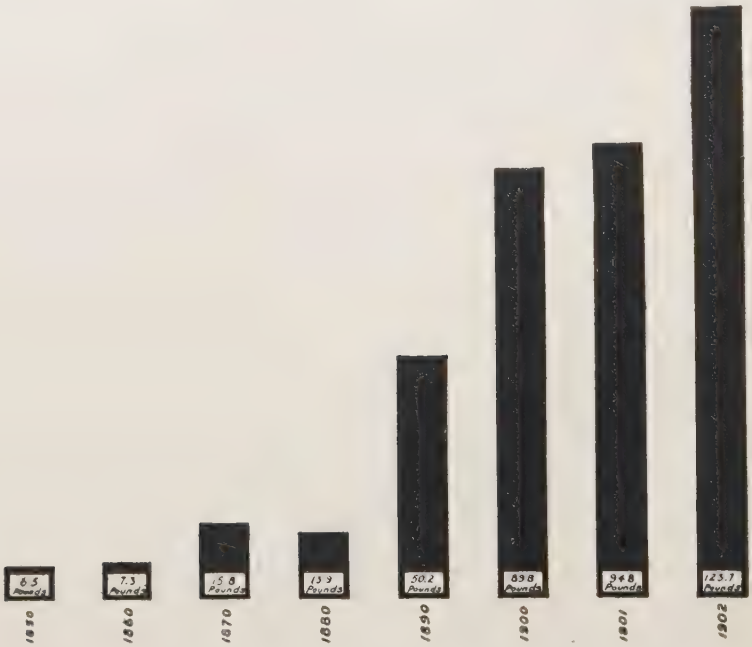
Census Year.	Population.	Domestic production, in barrels.	Total per capita, in pounds.	Number of mines or quarries (*c*).	Total number of barrels per mill.	Barrels of Portland cement per mill.	Barrels of natural cement per mill.
1850	23,191,876	509,110(*b*)	6.5	35	14,546(*d*)	.....	14,546
1860	31,443,321	767,080(*b*)	7.3	14	54,790(*d*)	.....	54,790
1870	38,558,371	2,033,893(*b*)	15.8	45	45,198(*d*)	.....	45,198
1880	50,155,783	2,072,943(*b*)	13.9(*a*)	28	74,034(*d*)	.....	74,034
1890	62,622,250	7,776,616	50.2(*a*)	79 { 16 Portland 63 Natural	98,438	20,970	118,113
1900	76,303,387	16,865,539	89.8(*a*)	114 { 50 Portland 64 Natural	147,940	169,640	130,990
1901	80,000,000	19,796,048	94.8(*a*)	116 { 56 Portland 60 Natural	170,720	227,000	118,080
1902	81,500,000	25,274,949	123.7(*a*)	127 { 65 Portland 62 Natural	199,016	265,000	129,750

(*a*) Includes imports.
(*b*) Estimated from reported valuation at $1.00 per barrel.
(*c*) Establishments.
(*d*) Estimated from reported valuation at $1.00 per barrel, and assumed to be all natural rock cement.

These figures show that in 1850 there were 35 cement mills in the country, all making natural cement and having an average annual capacity of 14,500 barrels a year. In 1890 there were 16 Portland cement mills of an average capacity of 21,000 barrels, and 63 natural cement mills with an average output of 98,400 barrels. In 1902 there were 65 Portland cement mills averaging

205,000 barrels, and 62 natural cement mills averaging 199,000 barrels.

From the above an excellent opportunity is afforded of comparing the relation of the natural cement industry to the Portland cement industry in this country, and when taken in connection with the foregoing table of imports of foreign cement and manufacture of American Portland cement, give an excellent idea of



PER CAPITA CONSUMPTION OF NATURAL AND PORTLAND CEMENT FROM 1850 TO 1902

how Portland cement of American manufacture is gradually taking the place of all other cements in this country.

Still more marvelous is the growth in the consumption of natural and Portland cement per capita in this country. In 1850, when construction based on scientific principles was in its early days, each citizen required an average of 6.5 pounds. Just before the Civil War about 7.3 pounds were enough. In 1870, when

things were doing well generally, 15.8 pounds were ample. In 1880, after the Northern Pacific episode, when construction was checked, the necessities of the average citizen fell to 13.9 pounds. In 1890, however, people were realizing that permanent construction was desirable, and 50.2 pounds were required. By 1900, 89.8 pounds were necessary, and in 1902 this figure rose to the surprising total of 123.7 pounds.

In addition to the fact of this great consumption in the United States, and of the fact of the decrease in imports, it is an additional source of gratification to American manufacturers to know that the imports of Portland cement to the United States during the present year 1904, are not likely to exceed 500,000 barrels, an amount just about equal to American exports of Portland cement.

The figures above practically show the condition of the trade in this country, but for purposes of comparison for those who are looking into the production of Portland cement as a world industry, it may be stated that this country to-day has a producing capacity of nearly 30,000,000 barrels, and according to the best figures obtainable for the year 1903, actually produced 21,000,000 barrels, all of which was used here. Germany, which is recognized as the leading world's producer, had in 1903 a capacity of 30,000,000 barrels, sold about 20,000,000—of which 4,500,000 were exported, leaving the consumption of Germany about 15,000,000 barrels, as compared with the consumption of this country of 21,000,000 barrels of American manufacture and 2,500,000 barrels of imported manufacture, and about 500,000 barrels of slag cement, a total of 24,000,000 barrels. It is thus seen how fast our country is coming to the front as a great consumer of Portland cement.

In connection with all the foregoing, it may be stated that most of these important results are due to American engineers and their faith in the American product, and much more will be due to our own Society, by reason of the care and attention it has given to the preparation of Standard Specifications for Portland cement. These specifications which are before our body to-day have been prepared by a joint committee, composed of representatives of the American Society for Testing Materials, American Society of Civil Engineers, American Railway Engineering and Maintenance of Way Association, and the Association of Portland Cement Manufacturers, under Professor George F. Swain as chairman.

Needless to say, the task has been long and arduous, but it is hoped not a thankless one. It is the belief of the writer that when specifications for Portland cement have become standardized in this country, as they will certainly become through the work of our Society, there will be no limit to the growth of the industry. The standardization of specifications will allow manufacturers to produce a more uniform and regular, and by the very fact of standardization, a cheaper article, and consumers will have an article of the best quality, thoroughly governed in its production, and one which will in the next period of our growth prove the cheapest and safest of building materials.

PRACTICAL CEMENT CONTROL.

By Charles F. McKenna.

I believe that the request of the Committee in charge of the proceedings of this meeting is that the papers presented here be limited in presentation to a duration of fifteen minutes, and this suits exceedingly well in the case of the paper that is before you.

I think that brevity, if it promotes clearness, is very much needed in the discussion of practical cement control. The details of every conceivable test have been published and republished, experimented upon, tried and retried, discussed and again discussed, and some of the results, even where the subject and work were meritorious, have been to confuse the minds of engineers, architects and constructors. There is a mass of misconception about Portland cement still remaining and it is more important to correct this than it is to publish at once a standard specification.

What is the object of the engineer and constructor in adopting control of cement? It is the same as his object in controlling other general materials, timber, stone, steel, etc., viz: to see that the material is of the quality that is called for. Now this term not only includes the elements of durability, but involves the question of full value in honest weight, and honest avoidance of additaments of inferior value. The means he will adopt to reach his object will be by a plain statement of his requirements, called the *Specifications*, and by a series of trials of what is being offered to him for his work, called *Inspection*. These dual means to his end cannot be separated. Specification, without inspection, is almost useless; inspection, without specification, cannot enforce condemnation. A defective specification will defeat the whole object of these trials, while defective testing will certainly also do that. The specification must be clear; it must be full and extended enough to cover every point which will lead to a correct judgment of the cement; it must above all not fail in its purpose by reason of loose statements, low standards, or omitted criteria. The inspection element in control comprises sampling, testing and judgment. The inspec-

tion must be practical. That is, it must furnish definite results, and this must be done at a place, in a manner, and at a cost that fit the purpose. Obviously the means of testing have to be supplied, and they usually consist of a few instruments of precision, which it is necessary to keep in proper condition. It would seem not always easy to keep cement testing within the limits of practical cost. Yet no one wishes to pay an excessive insurance premium for insuring any risk.

These are the elements of the question of practical cement control. What are the detailed recommendations?

For small work, the engineer or architect will be concerned only with his specification; for the second element, the inspection must be done by a sampling and laboratory force which he cannot keep employed, but must obtain from a chemist specializing in materials. For large works this additional element can be supplied upon the works, and he has a field for his personal control which is open to him to the fullest. And it is to such situations that the present paper mostly applies.

The Specifications.—These should provide for the full and careful sampling of the lots of cement offered for the work; for their preservation till judgment has been passed upon them; for the weighing of occasional packages; for the determination of the specific gravity, of the fineness, setting time, tensile strength, constancy of volume, loss on ignition. Specifications seldom contain all these features, and at times are so worded that the engineer receiving his returns from the laboratory having on their face only the returns called for in his incomplete specification, will be unable without being aware of it to pass a proper judgment upon the cement.

In tensile strength we have a feature which has always been much misunderstood, and in which we have perhaps the best field for reform in the criteria of cement. The fallacies involved in the 24-hour test are so numerous that certainly the labor involved in that test should be eliminated, gaining thereby one point in economizing the cost of testing. But it should be replaced by a three-day test in case the cement is not to be held over two weeks, and this followed by a seven-day test will furnish information enough, along with the soundness and other tests, to pass a fair judgment upon the sample. When this again is followed by fourteen and

twenty-eight day tests the character of the cement can be well understood. The day is coming when the tensile strength at any one or two periods will not be quoted as indicative of the quality of a cement, but the curve of hardening as determined by two observations within a week, and two more within the month, will rule as being more illuminating as to the character of the cement.

It is customary to make five briquettes in each series and to average the results of the figures so obtained on all. This rule is followed by some inspectors even when the results show gross discrepancies. Those who are accustomed to manipulative experiments and to logical deductions from numerical results know how to ascribe values to their results in a better way than this, and how to eliminate figures which are obviously in error. Such operators in cement testing can lessen the work by making only three briquettes. It is in this field that much good can be got by giving special training in a school of cement inspection.

Emphasis must be placed on the rule that we must have as many factors as possible for a judgment of cement. I know of no single test which by itself would serve to give the hallmark to a cement. There is no touchstone test for this very ordinary-looking but very complex substance. To reject a cement upon one symptom which is indefinite may be productive of harm, but as in the stability of important structures the structure must get the benefit of the doubt, so engineers and inspectors of cement are justified in refusing to use cements which leave them in this doubt. In work of short duration and unimportant character, with no danger to life or with large factor of safety, or in immense works where great lots are being used and the doubt is only as to a unit lot, the manufacturer should be given the benefit of the doubt.

But should there be any doubt? There may be, but it should be small. As said before, the attempt to form a judgment from the results of a suite of tests is very much like diagnosis of disease. It is a complicated mental process based upon a number of observations and experiments not all of which are positively known to be exact or to rest upon an infallible basis, but all of which pointing in the same direction carry conviction to the mind. It is true chemistry and physics are exact sciences, and exact measurements are expected to be used, but indefiniteness of detail is not always inexactness.

Chemical analysis is not to be recommended as a means to be resorted to unless the cement is coming in large lots and the samples are representative of the general output of the mill. Loss on ignition, however, should be frequently determined, and perhaps alkalinity of water solution. To call for detailed chemical analyses of samples representing small lots will result in either an excessive cost of insurance or the employment of a grade of chemical talent which will be no insurance.

As an example of sustained, fair and conclusive work of inspection of cement, I would refer to that inaugurated by Mr. Edwin D. Graves, of Hartford, Conn., upon the large work of the stone bridge to be erected at that city for the Connecticut River Bridge and Highway District Commission, a contract which will involve the use of 100,000 barrels of Portland cement, more or less.

The specifications are as follows:

Cement.

12. All cement shall be pure American Portland. All cement shall be dry and free from lumps, well seasoned and free from slag or other waste products, such as ground limestone or sand. Manufacturers must guarantee that all cement has been seasoned or subjected to aeration at least thirty days before leaving the works.

Well-known brand of cement.

Only high-grade American Portland cements of established reputation, which have been made by the same mill and process and used successfully under similar conditions to those of the proposed work, will be considered, and the decision of the Engineer shall be final. The Contractor shall furnish the Engineer with all information which he may require in regard to the record or history of the cement which he proposes to use. It is desirable that no change in the brand or quality of cement be made throughout the work, and considerable preference will be given to that cement whose makers can guarantee to supply regularly and on time the entire quantity required.

Tests.

Tests, in general, are to be in accordance with the rules of the American Society of Civil Engineers, except where otherwise noted or required by the Engineer.

All cement is to be furnished either in first-class barrels or duck bags, and each package must be perfect, and have the name of the manufacturer clearly marked upon it.

30 days' supply must be kept on hand.

The Contractor must keep on hand in the storehouse at the work a sufficient supply, in the original packages, to allow a thirty-days test of each lot or consignment of cement before any of it will be allowed to be used in the work. The cement must be stored in tiers in a suitable dry storehouse, at least

one foot above the ground, so that every bag or barrel is accessible for sampling and marking. Each lot or consignment received must be piled by itself and its date of receipt plainly indicated. In general, samples shall be drawn from one barrel in twenty-five or one bag in one hundred, but the Engineer reserves the right to sample any or all packages received, and to order a retest at any time. Sampling.

No cement can be used in the work until it has been accepted by the Engineer, and each package, after acceptance, must bear an acceptance tag or label, to be affixed by the Engineer to each lot which has satisfactorily passed all the tests which he desires. Acceptance.

Any cement which has been rejected shall be immediately removed from the storehouse and from the vicinity of the work.

As the accepted cement is removed from the storehouse for use in the work, the tags or labels must be removed or destroyed by the Engineer.

Each barrel of cement must weigh at least 375 pounds net, and will be figured as four cubic feet of cement, loose measure. Each bag is figured to contain one-fourth of a barrel, both in weight and measure. Weight and volume.

The proportion of lime to silica shall be about three to one. Chemical composition.

Sulphuric acid, less than 1.75 per cent.
Magnesia, less than 3 per cent.

Fineness shall be tested by sieves of best standard make: Fineness.

No. 100 sieve, 10,000 meshes per square inch.
No. 200 sieve, 40,000 meshes per square inch.
95 per cent by weight must pass a No. 100 sieve.
75 per cent by weight must pass a No. 200 sieve.

The specific gravity shall be between 3.10 and 3.20. Specific gravity.

Initial set not less than one hour.
Final set not over eight hours. Set.

Two cakes of neat cement shall be molded on glass and be made about three and one-half inches in diameter, three-eighths inch thick at the center, drawn down to a sharp edge at the circumference. One cake shall be immersed in cold water, after having set hard, and then examined from day to day for a period of seven days, in order to detect surface cracking and warping. The other cake, after having set hard, shall be immersed in water at 70° F., supported on a rack above the bottom of the receptacle, and the water gradually Constancy of volume.

raised to the boiling point and maintained at this temperature for twenty-four hours. Examination of the cake at the end of that time must show no signs of checking, cracking, or distorting. The surface color of these cakes, when left in the air until they are set hard, and after immersion in both hot and cold water, must be uniform throughout, of a bluish or greenish-gray, and free from light yellowish blotches.

Failure to pass boiling test not conclusive.

Should the sample fail to pass the hot water test, the Engineer reserves the right to reject the lot or to order a retest, or to subject the sample to chemical analysis in order to determine whether said failure to pass the hot water test was occasioned by free lime or other deleterious conditions. The Engineer may withhold his approval until the result of the twenty-eight day test of the cake in cold water can be observed, or he may order a new boiling test from new samples drawn from the same lot but from different packages. If the twenty-eight day cold water test or the second boiling test is unsatisfactory, the lot must be rejected.

Tensile strength.

Neat briquettes must stand a minimum tensile strain per square inch:

24 hours in air, 200 lbs.
24 hours in air and 6 days in water, 500 lbs.
24 hours in air and 27 days in water, 650 lbs.

Sand mortar briquettes, three parts sand (standard crushed quartz) to one part neat cement, must stand a minimum tensile strain per square inch without breaking:

1 day in air and 6 days in water, 175 lbs.
1 day in air and 27 days in water, 275 lbs.

Standard sand.

The standard quartz sand shall pass a standard sieve of twenty meshes per lineal inch, four hundred meshes per square inch, and be all retained upon a standard sieve with thirty meshes per lineal inch or nine hundred meshes per square inch.

The tensile strength of both neat and sand briquettes shall show a satisfactory increase of strength up to periods of one year. The Contractor shall, if required, furnish previously obtained evidences of the strength of the cement at periods of three, six, nine, and twelve months.

Mixing.

When making briquettes, well-dried cement and sand will be used. Neat cement will be mixed with twenty per cent of water by weight; three to one sand and cement mixture, with twelve and one-half per cent of water by weight.

13. The mortar shall be made up of cement and sand in varying proportions, as specified in each class of work in which it is to be used. The ingredients shall be mixed by actual measure, and one barrel of cement shall be figured as four cubic feet loose; one bag of cement shall be figured as one cubic foot. Cement and sand shall be thoroughly mixed dry before adding water. Mortar shall be mixed in proper mortar beds or by proper machinery, and shall be used before it begins to take its initial set. Any mortar which begins to show this set, or which is damaged from any cause whatever, shall be thrown away. Mortar.

14. In each part of the work the different mixtures of concrete will be known by the proportion of cement, sand, and stone contained therein; for example: A 1-2-4 mixture will contain one unit by measure of cement, two units by measure of sand, and four units by measure of stone. The sand and stone shall be actually measured in a manner satisfactory to the Engineer. The cement will be estimated as four cubic feet loose cement per barrel, and one cubic foot per bag, as one-quarter barrel. Concrete. Measurement of materials in mixture.

In general, concrete shall be machine mixed in a cubical mixer. The cement and sand shall be dry mixed, then the proper amount of water added to thoroughly mix the mortar, then the stone added and thoroughly mixed with the mortar. The amount of water required will depend upon the place in which the concrete is to be used, but, in general, rather wet concrete will be required. Cubical mixer.

In hand mixing, a smooth, clean, close platform of ample area must be used, the volume of stone spread out on one side in a flat layer not over one foot in thickness within a frame of one or two yards unit. The dry sand and cement shall be mixed adjacent thereto until of a uniform color. The stones shall be wet and the sand and cement mixture spread over them in a uniform layer, and properly moistened with a fine sprayer. A batch so prepared shall be turned over three times by shovelers working toward each other from opposite sides, care being taken not to heap up the batch, but to maintain it of uniform thickness after each turning. Hand mixing of concrete.

Concrete which has begun to set shall be thrown out and not used in any part of the work.

Concrete will generally be deposited in layers not exceeding one foot in thickness, and shall be properly rammed and leveled in place with iron rammers, weighing twenty-five to thirty pounds, care being taken that all edges and corners are filled with mortar. Depositing concrete.

All surfaces where new concrete is to join old concrete or masonry shall be thoroughly cleaned and scrubbed, rough- Joining new work with old.

ened if required, and washed over with a thin Portland cement wash before depositing concrete. The shape of the surface of concrete work when work is suspended shall be determined by the Engineer, according to the exigencies of each case.

Cement finish. When cement finish is required on the face of concrete work, it shall be deposited inside the forms at the same time as the concrete, and in such a manner as to bond with it. This cement finish will, in general, be mixed in the proportion of 1–2.

Protect while setting. All concrete or cement finish shall be protected from the sun by covering or awning, and be kept wet when setting, for such time as the Engineer may require.

Masonry in freezing weather. 15. The laying of masonry or the depositing of concrete in freezing weather shall be under such requirements as the Engineer may determine in each particular case. The housing in of the whole structure and heating by proper means is the method preferred. The necessary means of removing frost from all the materials employed shall be such as meet the approval of the Engineer.

Masonry. The word "Masonry," as used in this agreement, shall include stone work of all classes, concrete work of all classes, and concrete and stone work together of all classes, each complete in place.

After the publication of these specifications, the writer was called into consultation to arrange for the inspection of the cement.

A laboratory has been installed with a screw power testing machine mechanically operated, with the necessary sieves, balances, moulds, moist closet, tanks, and accessories of all kinds for each of the tests. Sampling is thoroughly and systematically done, and one of the most notable features of this division of the work lies in the way in which the samples are used. On the arrival of a car containing 600 bags or thereabouts a sample is taken from every 100 bags as they are being taken to the storehouse, and these are mixed to form the sample by which that car will be judged for acceptance or rejection. The tests made on this sample are embodied in what is called the "Acceptance" Cement Report, and they include the fineness, soundness, setting time, tensile strength neat and sand at 7 days and 28 days. Now four such car samples are subsequently taken and mixed to furnish the data for the "Mixed Sample" Cement Report, in which the features already determined are entered by their average, and in addition briquettes are made so that data will be furnished for the three months, six

months, and one year reports. It is believed that the Chief Engineer has by this method the fullest knowledge of the character of the cement which is offered to him and of that which has gone into his work that it is possible to have of it, and at a very reasonable cost. Five-inch concrete cubes are also made from the mixer, and these are laid away for testing at long periods. Mr. Graves discovered that he secures better results by making a prism of such concrete several feet long and having the cubes sawed out of it by the marble cutter.

A modification of the procedure of sampling has later been introduced to further facilitate the direct transmission of the cement to the concrete mixer without passing through the storehouse, and this may be adopted for all of the open season. It consists in sampling certain bins at the cement mill by means of numerous samples and locking and sealing these bins until the samples have been through the regular series of tests at the laboratory at the bridge site. Cars are loaded only from the accepted bins and the cement is sent forward for transhipment at Jersey City, where another representative of the laboratory certifies to the proper transhipment and sends forward to the Hartford office all information about the particular lot of cement on the barge. Complicated as this may seem, the system and conditions are such that the Engineer of this great work can congratulate himself on having cement inspected at a cost which is very reasonable.

I should sum up my recommendations for practieal cement control in the following way:

Specify fully and in terms that can be practically applied upon inspection, and practically met by the manufacturers.

Inspect by means of least necessary number of samples submitted to numerous but simple tests of which the methods are exact.

Let the judgment be based upon a summary of all results.

Adopt chemical analysis only when all the elements of control are confided to an expert chemist.

DISCUSSION.

Mr. Humphrey. RICHARD L. HUMPHREY.—As I understood the specifications, in Dr. McKenna's paper, he recommends a fixed percentage of water—20 per cent.—for all Portland cements for making briquettes.

It think it is an absurdity to fix definitely in a specification the percentage of water to be used in making briquettes. The chemical composition of cement varies considerably, and as the phenomenon of hardening which takes place upon the addition of water is simply a process of crystallization, the amount of water required for the purpose will vary, not only with every brand, but often with every shipment. The quantity of water required may vary from 18 to 27 per cent., depending on chemical conditions.

The fineness to which the cement is pulverized also affects the percentage of water required; other conditions being the same the finer the cement the greater the quantity of water. The age of the cement also affects the quantity of water required; a thoroughly seasoned cement usually taking less water than a freshly ground cement. It is therefore, impossible as a general proposition to fix definitely the percentage of water to be used in testing cement.

Mr. McKenna. C. F. MCKENNA (by letter).—A fixed percentage of water for all cement samples is of course not recommended. There are other points in the specification which the writer would not be responsible for. It was quoted only because it was a good example of a comprehensive specification showing that the engineer had his subject well in hand, and that it was not difficult for the expert in materials called in after the contract was let to design a system of inspection which would secure excellent cement.

SOME POSSIBLE BY-PRODUCTS IN THE PORTLAND CEMENT INDUSTRY.

By Clifford Richardson.

In the course of the investigations conducted by Dr. W. H. Hillebrand, at the request of the Committee on Uniform Methods of Analysis of Materials for the Portland Cement Industry, he found that when a raw mixture which contained .69 per cent of potash and .22 per cent of soda was ignited in a platinum crucible for one hour over an ordinary blast lamp, the resulting cement contained but .07 per cent of potash and .09 per cent of soda. The alkalies had been nearly completely volatilized and the potash more completely so than the soda.

It at once became of interest to determine whether the same thing took place in the industrial production of Portland cement clinker. It was found that from a raw mixture, made from marl and clay, which contained the percentages of alkalies mentioned above and which should, in consequence, contain 1.26 per cent of potash when burned if none of it was volatilized, since the loss on burning was 37.50 per cent, .65 per cent was carried off in the flue gases at the temperature of the rotary kiln. An investigation of the flue dust proved that the alkalies were carried further than the point where this material is deposited, and it is apparent that by conducting the gases through a long horizontal chamber where the temperature could be reduced to a point low enough to permit of the deposit of the potash, this could all be collected, perhaps aided by a spray of water or steam.

The importance of this discovery is apparent if a calculation is made of the actual weight of potash which is produced and lost in this way in a cement plant turning out 4,000 barrels a day, or 700 tons of material. Six-tenths of 1 per cent of this would mean 4.2 tons of potash, which now goes to waste, but which could be readily collected and have a value of at least $12 per ton, that of kainite with 12 per cent of potash and with a probable value

of $45 per ton, that of the commercial muriate used for fertilizing purposes. In the later form our 4.2 tons of potash would be the equivalent of 6.6 tons of muriate, so that, allowing the excessive sum of $50 per day for the expense of the process and interest charges, the profit from a single plant of the size mentioned would be between $100 and $200 per day. It would seem that the development of the process would be of commercial interest.

In conclusion, it may be said that Dr. Hillebrand has an application pending for a patent covering it.

DISCUSSION.

R. K. MEADE.—I made some experiments some time ago, Mr. Meade.
which were detailed here the other morning at the meeting of the Association of Cement Manufacturers, to determine the losses other than carbon dioxide and water which occurred in the rotary kiln. These losses I found were principally sulphuric acid, potash and soda. By an analysis of the raw material entering and the clinker coming from the kiln between 60 and 70 per cent. of the potash, and between 20 and 30 per cent. of the soda present in the raw material were driven off. From the figures of these tests, a one-thousand-barrel plant would throw off about 3,600 pounds of alkali; but in order to catch this, there would have to be taken care of at least 2,000,000 pounds of gas at a temperature of about 900° C. It would seem that, in order to recover this alkali economically, it would be necessary to introduce very much less air in the kiln, so that there would not be such enormous quantities of gas to look after. It would not seem to me quite practical to take care of 2,000,000 pounds of gas at a temperature of 900° or 1,000° C.

SOME NOTES ON THE BOILING TEST FOR CEMENT.

By Frederick H. Lewis.

It is difficult for most of us to arrive at conclusions purely by the light of reason, to deal with every syllogism from its premises to its conclusion. We are all disposed to argue somewhat on the basis of our prejudices or to refute others because of the prejudices which we ascribe to them. The Navy Department of the United States Government has given us to understand that it views askance the specifications for Portland cement prepared by a committee of this Society because these specifications take cognizance of established manufacture in preference, perhaps, to venturing upon modifications of manufacture. If the report of this committee is so regarded it can hardly be expected that the suggestions of the speaker will be viewed apart from his interests as a manufacturer. Let us then begin by admitting these interests or prejudices, whichever you may like to call them. The truth is, however, that the purpose of this paper is not especially to discuss the advisability of these tests for cement or to oppose them, but it is rather to consider the modification of manufacture suggested by these tests, to raise the question whether such a resultant product is desirable or undesirable, and to rest the subject there for your consideration.

In passing, however, it may be said that the speaker has on one or two occasions ventured to intimate that there was no competent opinion in favor of accelerated tests for cement, only to find that this view was very much resented. There are, it appears, so many young gentlemen who have made some dozens, some scores or even some hundreds of boiling tests, and who are in consequence entirely satisfied of their intimate knowledge of the subject. But is it not a fact that American scientific literature is almost entirely barren of that kind of careful investigation which is intended to establish the reliability of cements for practical purposes and the value of accelerated tests as criteria of quality? If the speaker is correctly informed, some at least of these tests have turned out so

badly for the high-testing boiling cements, that the results have not been published.

Whether, however, these tests be good or bad, desirable or undesirable, does not especially concern this paper. The manufacturer must evidently make what people want, and this is now a cement to pass some sort of boiling test or the later atrocity of a steam test just perpetrated by the Society's committee. And almost all manufacturers have sufficiently studied the problem to meet these requirements with reasonable regularity. A study of the conditions precedent to doing this suggests certain advantages which arise from variations in the composition of the cement. Suggests indeed, that for testing purposes some radical innovations might be adopted. It is the object of this paper to briefly deal with this subject.

In comparing two cements of similar composition, or in varying within certain limits the composition of the same cement, the following conclusions are reached, to wit, other things being equal:

First. The higher the silica the better the cement boils.

Second. The higher the oxide of iron the better the cement boils.

Third. Within certain limits the higher the sulphuric acid the better the cement boils, and

Fourth. Within the limits of approved formula the higher the lime the better the cement boils.

Magnesia appears to be entirely inert. Whether alumina is detrimental in itself, or whether its presence is disadvantageous, because it reduces the amount of silica and oxide of iron which the cement could otherwise carry, the speaker is not prepared to say, but it is quite clear that it is advantageous to have the alumina low.

It is hardly necessary in this company, familiar with the chemistry of cement and the practical limits of the Portland cement formula, to point out in any detail the limitations which apply to these general conclusions. Within these limitations the data above indicate the lines on which cement of boiling quality can be proportioned, and suggest that an outline or skeleton formula for boiling cement should read something like this:

Lime	66	per cent.
Silica	25	"
Oxide of iron	7	"
Sulphuric acid	2	"

A cement of this exact composition could be produced experimentally. The speaker has not done this, but there are sufficient precedents for saying that it undoubtedly could be made, and there can be little doubt that it would be Portland cement with very desirable qualities so far as meeting laboratory tests is concerned. It might have some drawbacks, but it may be safely said that it would be:

First. Always slow setting.

Second. That it would stand all kinds of accelerated tests.

Third. It would have high specific gravity.

Fourth. It would show high tests at short periods in neat and sand mortars.

Fifth. It would escape a certain criticism now in vogue of Portland cement for sea-water work.

This formula, it will be observed, approaches much more nearly that of the hydraulic limes than it does to the generally received formula for Portland cement. The celebrated hydraulic limes of France, with their extraordinary sand-carrying capacity, are made from siliceous limestones free from alumina. The theoretical formula for this is given by M. Le Chatelier as follows:

Silica	16.6 per cent.
Carbonate of lime	83.4 "

As actually made, the best grades of these hydraulic limes show an average analysis which will read about as follows:

Silica	25 per cent.
Alumina	2 "
Iron oxide	1 "
Lime	71 "
Magnesia	1 "

Now these hydraulic limes are burnt at the temperature of a limekiln, and even under these conditions, the silica, which is in a fine state of subdivision, combines the greater part of the lime. The product is subjected to air slaking before shipment, and when prepared in this way these limes not only show extraordinary sand-carrying capacity, but are entirely sound under accelerated tests.

In actual manufacture there should be no particular difficulty in making a silica-iron-lime cement. For practical purposes it is only necessary to approach it, and indeed better, for most purposes, not to eliminate all the alumina.

A cement of about the following composition would present no serious practical difficulties by the dry way:

Lime	64.5	per cent
Silica	22.5	"
Iron oxide	5.0	"
Alumina	3.0	"
Magnesia	2.5	"
Sulphuric acid	1.5	"
Undetermined	1.0	"

Since coming here the speaker is convinced of the growing importance of being able to make cement by prescription from three, four or even more constituents. Having adopted a standard specification, it is even now evident that certain of the larger corporations are going to say, "We do not care what the cement costs; make us what we want." And it appears that one of the things they want is a low tensile test; another is a still further limitation of the sulphuric acid. These requirements are difficult to meet unless we can eliminate a part of the alumina, unless indeed we modify manufacture to meet them.

In comparison, a typical Pennsylvania Portland cement to day analyzes about as follows:

Lime	62.0	per cent.
Silica	21.5	"
Alumina	8.0	"
Iron oxide	2.5	"
Magnesia	3.3	"
Sulphuric acid	1.7	"
Undetermined	1.0	"

The difference between these formulas is quite marked. The essential difference is that the formula suggested elininates a large part of the alumina in favor of silica, lime and iron oxide. The old formula approaches the Roman cement basis, the new approaches the hydraulic limes. One feature of the Roman cements is retained, to wit, the high iron. As a general rule, the natural or Roman cements abroad contain after calcination from 4 to 6 per cent of oxide of iron. The proposed formula for boiling cement, therefore, follows the general figures of the hydraulic limes by reducing the alumina, but contains the high iron of the Roman cements.

What briefly is there to be said of the elimination of alumina? There can be no doubt that high alumina in cement, and especially in rotary kiln Portland cement, has certain actual disadvantages. But the earlier American and foreign Portland cements which contained even higher percentages of alumina than at present had the quality of hardening progressively up to periods of four or five years, which has not been at all equalled by later products. This may or may not be important. Views differ.

But it may be said on the other hand that the general formula now in use for Portland cement was developed for special conditions which do not obtain now for the major part of the industry. It reverts to the earlier practice abroad which was by the wet or humid way. For this purpose a clay was required which was free from sand or uncombined silica of any kind, so that the mixture could be made by the inexpensive wash mill process, without any grinding of the raw materials. This condition still prevails in the wet process, as raw materials which require wet grinding greatly increase the cost of production. But there is no special reason why the dry process should continue to follow this precedent if important advantages are to be gained by departing from it. You have, then, gentlemen, a constructive outline for a formula which is believed to be the logical development of the present testing requirements. What do you think of it?

DISCUSSION.

CLIFFORD RICHARDSON.—I have been very much interested in Mr. Lewis's paper. It happens that I have made a cement in which the alumina has been replaced by iron of exactly the kind that he has described. The peculiarity of this cement is that owing to the absence of the quick-setting compounds of alumina and lime and their replacement by compounds of iron and lime of very low hydraulic value, it sets extremely slowly. The hydraulic properties of such a cement are derived almost entirely from tri-calcic silicate which is present, which is known to be a material which sets extremely slowly. After an interval of 28 days, however, briquettes made with this iron cement gives a tensile strength of 570 pounds per square inch. Mr. Richardson

It also possesses the peculiarity that the iron and lime compounds which it contains do not dissolve to any appreciable extent in tri-calcic silicate. The latter, therefore, crystallizes out of the ferruginous magma as colorless crystals. This cement, therefore, does not correspond at all to our ordinary industrial product.

In regard to the effect of the varying percentages of lime in a cement upon the time of setting and volume constancy, it is a fact that when the basicity is sufficiently high to correspond to a percentage of lime required for the formation of tri-calcic silicate and tri calcic aluminate, the cement will set much more slowly than one where the basicity is lower, if the burning is satisfactorily done in both cases.

F. H. LEWIS.—I have used a clay containing 4 per cent. of alkali in making cement. But a method for utilizing this alkali which can be operated without detriment to the proper output of the kilns strikes me as impracticable. Mr. Lewis.

R. W. LESLEY.—There is a cement made at the Krupp Iron Works in Germany, which is claimed to be a compound of lime and waste from chrome ores, or lime and waste produced in the manufacture of sulphuric acid from iron pyrites. In both these Mr. Lesley.

Mr. Lesley. cases, the cement contains large proportions of iron. These cements have the qualities of extreme slow-setting.

The particular purpose of these cements was to meet the criticism of Dr. Michaelis, who had attacked the stability of the modern Portland cement when exposed to sea-water.

Of course, in considering the addition of sulphate of lime, there comes a point where the cement would contain too large a percentage of sulphuric acid for safety, and this brings up the very interesting question whether there is not a possibility of producing a slow-setting rotary Portland cement with a less percentage of sulphuric acid than that now added in the form of sulphate of lime.

The speaker in 1895 and 1896 made some interesting experiments on that subject which were conducted in the laboratory of Messrs. Booth, Garret and Blair, covering a period of a year. The problem was the dealing with this doubtful substance known as gypsum or calcined plaster. As the only particular benefit to the cement by the addition of this substance was through the sulphuric acid contained therein, the thought came that the additional lime, being of no particular benefit to the manufactured product, that this might be eliminated entirely and sulphuric acid alone could be used in a dilute form.

These experiments were carried over a long time and were conducted upon manufactured cements and also upon clinker. Sulphuric acid was not the only acid used, but also hydro-chloric acid and phosphoric acid. All of these were found to have beneficial results in making the cement slow setting,.

From a practical standpoint, it was found that when sulphuric acid in diluted form was mixed with the cement material or clinker, by being sprinkled thereon or thrown thereon in the form of a vapor, a much smaller amount of sulphuric acid would accomplish a given result, than where the sulphuric acid was presented to the material in the shape of gypsum or calcined plaster. Therefore, if the tendency is to reduce tensile strains and reduce the allowable percentages of sulphuric acid, and at the same time require that the cement shall be slow setting, these requirements might be met by following out the lines covered in the experiments just described.

Mr. Cushman A. S. CUSHMAN.—I wish to say, that although we speak of

the presence of sulphuric acid in cements, no one supposes for a minute that it is present. It seems to me that it is entirely a question as to how the small amount of sulphur which is almost invariably present is combined, and the relation that these combinations bear to others with which they have been in contact at the high temperature of the kiln. Mr. Cushman

I think that all of us who listened yesterday to the very interesting discussion of the properties of the new steels, realize that the cement makers' problems are right in line with the new problems of the iron and steel industries. We ought to guard against drawing inferences merely from the percentage composition of a cement as shown by chemical analysis. What we have got to study is the effect produced by the solution of certain substances in others. In short the character of a cement is determined by the solid solutions that have been formed during the process of manufacture, more than by minute variations in chemical composition.

The steel men have found that this is true in respect to the products in which they are interested and the cement men are going to find themselves face to face with exactly similar problems.

TESTS OF REINFORCED CONCRETE BEAMS.

By Arthur N. Talbot.

It is intended here to review some of the results of tests of reinforced concrete beams made recently at the University of Illinois. In the investigation, an endeavor was made to determine the horizontal deformations of the beam during the progress of the loading and to find the amount of the stresses taken by the steel and by the concrete. Some attention was given to the effect of a change in the amount of metal used, the relation between elastic limit of metal and strength of the beam, and the position of the neutral axis.

Twenty-two rectangular reinforced concrete beams, 15 feet 4 inches long, 12 inches wide, $13\frac{1}{2}$ inches deep, were tested. The center of the metal reinforcement was 12 inches below the top of beam, but in some of the beams the rods were inclined or turned up at the ends. The span was 14 feet. The loads were applied equally at two points which divided the span into three equal parts. This loading gives a bending moment for the applied load of $\frac{1}{6}$ Wl at all points between the loads.

Chicago AA Portland cement bought in the open market was used. 1 to 3 mortar gave 233 pounds in 7 days and 400 pounds in 60 days. The sand was fairly clean and well graded in size, and contained 29 per cent voids. The stone was crushed limestone and ranged between $\frac{1}{4}$ inch and $1\frac{1}{2}$ inches size, and contained 44 per cent voids. The concrete was by loose volume, 1 cement, 3 sand, 6 stone. Concrete beams having the dimensions of the reinforced concrete beams gave a modulus of rupture of 343 pounds per square inch, counting both the applied load and the weight of the beam; 6-inch concrete cubes gave an average compression strength of 2,030 pounds per square inch in 60 days.

For the reinforcement, plain round rods, plain square rods, Johnson corrugated bars, Thacher, Ransome and Kahn bars were used. The amount of reinforcement varied from 0.6 square inch

of metal to 2.4 square inch, or from 0.42 per cent to $1\frac{2}{3}$ per cent of the area of concrete above the center of the reinforcement.

The yield point of the plain bars and of the Kahn and Thacher bars was between 32,000 and 35,000 pounds per square inch. The yield point of the Johnson bars was between 55,000 and 60,000 pounds per square inch. The yield point of the Ransome bars, not determined, was also high.

The beams were made directly on a concrete floor, except that a strip of building paper was placed under them, and they were not disturbed from this position until taken to the testing machine. The beams were tested at 60 days' age, the greatest variation from this being five days. This age was sufficient to reduce the variations in properties of the concrete due to differences in moisture and atmospheric conditions to a relatively small amount. Care was taken to have the work of mixing done uniformly, and the general appearance and behavior of the concrete was quite uniform.

The tests were made on an Olsen testing machine of 200,000 pounds capacity, with beam attachment. The extensometer device was carefully planned and calibrated, and it is believed that the measurements are trustworthy. Each frame of the extensometer device was attached to the beam by two pairs of screws, one pair generally being placed against the sides of the beam $1\frac{1}{4}$ inches below the top of the beam, and the other pair $1\frac{1}{4}$ inches above the bottom of the beam. The gage length was generally about 61 inches. Four extensometers, modified forms of the Johnson instrument, were used, their position being above and below the contact screws, but directly in line with them. They read to 1-10000 inch.

Diagrams.—Several typical load-deformation diagrams are appended, showing the relation between the applied load as ordinates (not including the weight of the beam, which has already stressed the fibers when the instrument is read at zero load) and the deformation per unit of length as abscissas. From the readings of the extensometers (which it will be remembered were above and below the beam and hence have magnified values) the shortening of the upper surface of the beam was calculated, and this shortening was divided by the gage length, which was in the neighborhood of 61 inches. This gives the compressive deformation per unit of

length marked "Upper fiber" on the diagrams. Similarly, the elongation of the beam at the level of the center of the steel reinforcement was calculated, and this elongation divided by the gage length is marked "Steel" on the diagram. The calculations are based on the assumption that a plane section before bending remains a plane section after bending, and that the steel elongates the same as the concrete at the same depth. Generally, the extensometers were taken off at the maximum load. The deflections at the middle of the length of the beam are also shown, a second scale of abscissas being used for this. The upper part of the diagrams gives the successive positions of the neutral axis obtained under the same assumptions as above. The ordinates denote this position in per cent of the distance from the top of the beam to the center of the steel reinforcement for the applied loads given on the scale of abscissas. The deformations and deflections are not generally shown beyond the maximum load, but the beams were all tested to destruction.

Table.—The table gives the stresses found in the steel reinforcement and the resisting moment developed by the steel at certain loads, as calculated by the methods and assumptions here described. The column "Load considered" is the applied load somewhat below the maximum load, and for which elongations and shortenings are definitely known, and hence is the load used in the calculations for the succeeding columns. The stress in steel is based upon the observed deformation for "Load considered" given in column headed "Total elongation of steel," using the coefficient of elasticity found for the naked steel bars. The symbol m represents the distance of the neutral axis below the top of the beam. The position of the center of gravity or centroid of the compressive stresses is taken in the calculations to be four-elevenths of the distance down to the neutral axis. This position is the result of analysis which can not be given here, and is close to the usual assumptions which take into account the varying relation between stress and deformation in concrete; and the difference between this position and that resulting from the assumption of a constant coefficient of elasticity need not be considered. The moment of resistance of the beam, neglecting tension in the concrete, is found by multiplying the tension in the steel as found from the deformation and coefficient of elasticity by the

distance from the center of the steel to the centroid of the compressive stresses in the concrete, $d-\frac{4}{11}m$, where d is the vertical distance from the top of the beam to the center of the steel reinforcement. It is readily seen that since the compressive stresses here considered are equal to the tensile stresses of the steel, this calculated moment of resistance is the same as if the moments of the tensile and compressive stresses had been taken about the neutral axis and added together. The method has the advantage that the compressive stress at the upper fiber does not enter into the equation. Of course it must be known in some way that this stress is within the ultimate strength of the concrete. The column $\frac{M_R}{M_B}$ gives the ratio of the resisting moment calculated as shown above to the bending moment at any point between the loads. The last column gives the same ratio with the bending moment augmented by the estimated proportion of the weight of the beam which the broken tensile fibers of the concrete has transferred to the steel. Further uses of the table will be apparent in the further references to it. It should be noted that for the Kahn bar on account of the somewhat smaller area of cross section just within the load points, due to the wings having been bent up, a comparison of the maximum load carried by these beams with that of beams with other forms of bars should not be made on the basis of the tabulated amount of metal. This decrease in cross section of the bar has only a slight effect on the average deformation for the gauge length used, and hence only slightly effects the comparisons made in this paper.

General Phenomena of the Tests.—Four stages of flexure are noticeable during the application of the loads. Through the first stage, as the load is applied, the action of the beam and the changes in deformations of upper and lower fibers are similar to those in plain concrete beams, modified of course by the metal reinforcement; and the resistance of the tensile stresses of the concrete is plainly apparent. When a load of about 4,000 pounds for 4-10 per cent reinforcement and of about 6,000 pounds for 1.5 per cent reinforcement is reached (equivalent to about 250 pounds per square inch tension in the extreme fiber of the concrete for its share of the applied load, and 350 pounds per square inch when the weight of the beam is considered), the second stage begins. The steel elongates more rapidly with the applied loading, there is

a similar increase in the compression of the concrete, the neutral axis rises, and there is a marked change in the character of the load-deformation diagram. While no cracks are visible to the naked eye at this second stage, it seems evident from the change in the diagram that much of the tensional value of the concrete has been lost. This stage may be called the readjustment stage. During the third stage the increments of the deformation of the steel are closely proportional to the increments of the loads, as shown by the straight line of the load-deformation diagram, and the compressive deformations generally approximate a straight line. During this stage vertical cracks appear, generally quite numerous and well distributed along the middle third of the length of the beam, and grow more distinct; but this appearance is not accompanied by any change in the character of the load-deformation diagram. This stage continues until a point at or near the maximum load is reached, except with those beams having an excess of reinforcement. The last, or stage of failure, begins at or near the maximum load. The beam deflects more and more, the load required to balance the scale beam becoming less and less. The steel stretches rapidly, the neutral axis changes position, and there is a more rapid compression of the upper fiber of the concrete, until finally the concrete crushes out at the top of the beam at a load less than the maximum and after the steel has stretched considerably beyond its yield point. The diagrams of Beams 14, 16, 17 and 19 show deformations beyond the maximum load. The exception to the above is in beams having more than 1 per cent of metal of 55,000 pounds per square inch elastic limit, or more than $1\frac{1}{2}$ per cent of 33,000 pounds elastic limit. In such beams the concrete at the top of the beam fails by crushing before the elastic limit of the steel is reached. In all the other beams the full compressive strength of the concrete was not developed at the maximum load. It may be noted that the deflection curve does not change its character until after the crook of the deformation diagram is well begun and again until after the yield point of the metal is passed, a result to be expected.

Maximum Load at Yield Point of Metal.—The observed deformations show that for beams not having an excess of metal (say not more than 1 per cent reinforcement with steel of 55,000

pounds per square inch elastic limit, nor more than 1½ per cent with steel of 33,000 pounds per square inch elastic limit for the concrete used in this work) the maximum load is nearly reached when the steel is stressed up to its yield point, and the load at the yield point of the metal may properly be taken as the ultimate strength of the beam. Actually, the maximum load is somewhat greater than this, averaging about 6 per cent more for all the beams, and in one case reaching 15 per cent more than the load at the yield point of the metal. The table shows that for the points chosen, which are just below the yield point of the metal and somewhat below the maximum load, the resisting moment for the steel (calculated by multiplying the stress found in the steel by the distance to an assumed centroid of the compressive stresses of the concrete and thus taking into account an equal amount of compression) is in general approximately equal to the bending moment due to the load, and hence that the moment of the tensile stresses of the concrete is negligible. The exceptions to this are (1) in beams with light reinforcement and low elastic limit metal, in which case the moment of tensile stresses in the concrete and also added stress in the steel at the vertical cracks may possibly account for the deficiency in the calculated resisting moment; and (2) in beams with an excess of metal, in which case the centroid of the compressive stresses, after the stresses approach the ultimate strength of the concrete, is probably lower than the position assumed, and hence the real moment will be less than the value here given. However, it seems that within the usual limits of reinforcement (say from ½ to 1½ per cent reinforcement with steel of 33,000 pounds per square inch elastic limit, and to 1 per cent with steel of 55,000 pounds per square inch elastic limit for this concrete) the calculated moment of the steel about the centroid of the compressive stresses is for the maximum load approximately equivalent to the bending moment, and no consideration need be made of tension in the concrete.

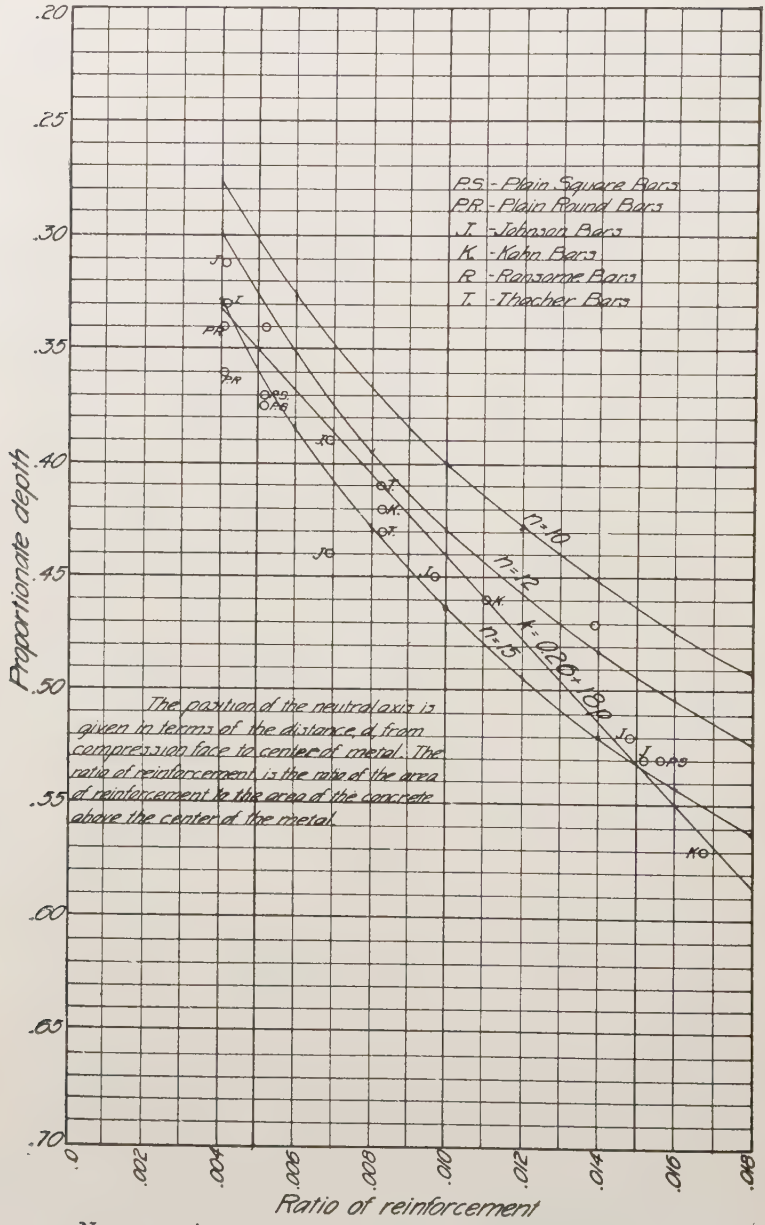
Stresses in Second and Third Stages.—Several interesting characteristics are apparent in the second and third stages. In the steel diagram the crook or elbow of the second stage and the reversal of curvature just after are characteristic. The increased elongation of the steel just after the crook seems to indicate that the concrete has broken in tension through a part of the depth of

the beam and that a part of the weight of the beam which had been taken by the tension in the concrete has now been transferred to make added tension in the steel. A line parallel to the load-deformation line above the elbow and tangent to the elbow lies above this line a distance equal to the amount of added load which may be expected from the beam. It is quite noticeable that during the third stage the load-deformation diagram is a straight line and that the increment of stress in the steel, calculated on the assumptions heretofore made, and hence its moment, is proportional to the increment of the load, though the stress in the steel is not proportional to the load. In fact, as may be seen by a study of the results, this increment in the resisting moment of the steel about the assumed centroid of compressive stresses is greater than the increment of bending moment of load; and in general for loads less than the maximum this resisting moment of the steel based on average deformation for the full gage length is considerably less than the bending moment. It seems probable that at the vertical cracks the steel is stretched enough more than the average deformation to give a stress which would make up the full amount of the bending moment. It is also found that for a load of 10,000 pounds the total stress in the steel is approximately the same in all the beams (about 24,000 pounds), although there is a difference in area of the steel and a slight difference in position of the neutral axis found for these beams. There is a similar uniformity at 15,000 pounds and at 20,000 pounds load for beams carrying such loads, the total stresses in the steel being about 42,000 and 64,000 pounds, respectively.

Conservation of Plane Section.—Some doubt has been expressed concerning the correctness of the time-honored hypothesis that a plane section before bending remains a plane section after bending, and the high results of tests of a special form of reinforcement made by loading with bars and brick has been cited in proof of the fallacy of this principle. To check its correctness, two extensometer devices were used on one side of the beam, the gage length being made the same in both cases by alternating the frames. One device had its contact points placed 11 inches apart vertically as usual, $1\frac{1}{4}$ inches below the top of the beam and $1\frac{1}{4}$ inches above the bottom. In the other the upper points were applied at the usual position, $1\frac{1}{4}$ inches below the top of the beam,

and the lower points were applied 8½ inches below the upper points. In another beam the vertical distance between contact points of the second set was made 6 inches. Readings with the two pairs of extensometers were taken simultaneously as the loading of the beam progressed. From these observations two sets of values of the elongation of the steel and compression of the concrete were determined and also the resulting positions of the neutral surface. The results agree closely, perhaps as closely as the variations in the transmission of the interior deformation to the contact point could be expected to give. It should be noted that this agreement does not hold for loads under 3,000 pounds. In general, however, the neutral axis as determined by one pair of extensometers is a uniform distance below that determined by the other pair, the average variation above the elbow of the curve being .27 inch for beam No. 22, and .12 inch for beam No. 27. It should be noted that the measurements were made with an arrangement of loading for which the vertical shear is nearly zero between gage points, and hence that there was little to cause distortion of section.

Position of Neutral Axis.—The successive positions of the neutral axis as determined for the various beams are shown on the diagrams. In general, the neutral axis may be said to rise during the second or readjustment stage, and then to remain in one position during the third stage until the maximum load is reached. For part of the beams the position of the neutral axis beyond the maximum load is shown, this position being higher than at the maximum load. For beams which developed the full compression strength of the concrete before the maximum load was reached, the neutral axis finally lowered somewhat. The neutral axis is in general lower than is given by several theories which have been proposed. The positions of the neutral axis during the third stage in beams with different forms of reinforcement agree fairly well with each other, as is shown by the diagram which gives the position of neutral axis for varying amounts of reinforcement. The writer has not been able to give much study to this phase of the matter, but the line $k = 0.26 + 0.18p$ gives the position somewhat accurately where k is the proportional depth of the neutral surface and p is the number of per cent of the steel area, the depth from the top of the beam to the center of the steel



NEUTRAL AXIS AND THE AMOUNT OF REINFORCEMENT.

Proportional depth of neutral axis is given in terms of distance from compression face to center of metal.

being used in both cases. Theoretical considerations indicate that the locus of the neutral axis should be a curved line, but its deviation from a straight line within the usual limits of reinforcement will be slight. The curved lines of this diagram are for calculated theoretical positions for three ratios of modulus of elasticity of steel to modulus of elasticity of concrete.

Value of Moment of Resistance.—It is no part of this paper to discuss formulas for strength of beams, but the equation given for position of neutral axis and the conditions found for maximum load suggest a method of calculation. The methods usually followed involve a calculation of the compressive stress in the upper fiber. The relation between deformation and stress in concrete is not definitely known and is probably variable. If it can be determined experimentally or otherwise that a certain per cent of reinforcement is required to develop the full compressive strength for a given grade of concrete, then for a smaller area of reinforcement the value of the compressive stress at the upper fiber need not be considered in the calculations. For beams and loadings where other considerations do not govern, the resisting moment may be found by multiplying the total stress in the steel by the distance to the centroid of the compressive stresses. If the condition herein shown, that a load only slightly less than the maximum load for the beam obtains when the steel is stressed to its yield point, the elastic limit of the metal may be used for finding the ultimate strength of the beam. For the position of the neutral axis given above, the following equation for the value of the resisting moment of a rectangular beam would result, neglecting any tensile strength of the concrete,

$$M = (0.906 - .065\ p)\ A\ S\ d,$$

where p is the number of per cent which the area of the steel reinforcement is of the area of the cross-section of the beam counting down to the middle of the steel, A is the area of the steel, S is the stress per unit of area in the steel, and d is the distance from the top of the beam to the center of the steel. For 1 per cent reinforcement this would become .84 A S d, and for $1\frac{1}{2}$ per cent reinforcement 0.81 A S d. For the concrete in the beams of this investigation the equations would hold if the reinforcement were not more than 1 per cent with metal of an elastic limit of 55,000

pounds per square inch, and not more than 1½ per cent with metal of an elastic limit of 33,000 pounds per square inch. An investigation of the limit of reinforcement for concrete beams of quite a range of mixtures and strengths would be of service, and also the determination of the position of the neutral axis with such concretes and for other shapes than rectangular. The writer believes that investigations along such lines will give the best basis for calculations of the strength of reinforced concrete beams.

Compressive Stresses.—Little can be said here concerning the compressive stresses in the concrete except to call attention again to the fact that the full compression strength was not developed even with concrete considered by many to be too lean, except in the case of beams having a large area of metal. It would seem almost that the ordinary formulas give a larger compressive stress at the remotest fiber than actually exists there. The relation between stress and deformation near the crushing strength of concrete is probably different from that assumed in such formulas.

Shear and Adhesion.—It had been anticipated that some of these beams, particularly those having a large area of reinforcement, might fail by shearing or more strictly by diagonal tensile stresses induced by shear. As a means of counteracting this, a portion of the bars in beams with 1 square inch metal or more were bent upward outside the one-third points of the beam and inclined diagonally to points about 4 inches below the top at the ends. The Kahn bars of course were not treated in this way. In no case was there a crack or failure of the kind usually attributed to shear. Whether such failure would have occurred with the bars continued horizontally to the end can not be told.

There was no indication of slipping of the rods in the concrete even with plain rods. A series of tests made to determine the adhesive bond between plain rods and concrete gave for the size of rods used an average of 300 pounds per square inch of surface of steel. For beams of the dimensions and method of loading used, this would indicate for the two sizes used a factor of safety against slipping of 2½ to 4 when the steel is stressed to 33,000 pounds per square inch, and of 1¾ to 2½ for steel of 50,000 pounds elastic limit when stressed to its elastic limit. For these beams, then, there is an ample margin against slipping.

Plain Concrete.—Diagrams of Beams No. 11 and 18 give load-

deformation diagrams for plain concrete beams. The deformations are given for top and bottom fiber, the beam being 15 feet 4 inches long, 12 inches wide and $13\frac{1}{2}$ inches deep, and loaded as were the reinforced beams. It will be seen that the neutral axis is very close to the middle of the depth of the beam. This would indicate that for this beam the coefficient of elasticity of concrete for tension and that for compression are approximately equal.

Other Tests.—Among tests made in connection with those described were a series of tests on plain concrete beams, tension, compression and shearing tests of concrete cylinders to determine relation between deformation and stress, and tension tests of reinforced concrete. The tests to determine the relation between stress and deformation were not complete enough to base conclusions upon. Tests were also made on reinforced concrete beams by taking off the load at two or more loads and noting the deformations as the load was being removed and again put on.

Conclusion.—It was found necessary by reason of limitations of floor space to reduce the number of beams for the several kinds and amounts of reinforcement below what was planned, and extensometer measurements were not obtained on three of the beams tested. However, the deflections and maximum loads of these three beams checked those of their mates very closely, and the general action and behavior of all the beams were so similar and uniform that the writer is disposed to place more reliance on the results of individual beams than he generally does in experimental work, and particularly more than can be placed on small concrete beams. While general conclusions are not to be drawn hastily or on slight evidence, the following deductions seem warranted for the beams and loading under consideration. 1. The composite structure acts as a true combination of steel and concrete in flexure during the first or preliminary stage, and this stage lasts until the steel is stressed to say 3,000 pounds per square inch and the lower surface of the concrete is elongated say $\frac{1}{10\frac{1}{3}00}$ of its length. 2. During the second or readjustment stage there is a marked change in distribution of stresses, the neutral axis rises, the concrete loses part of its tensional value, and tensile stresses formerly taken by the concrete are transferred to the steel. During this stage minute cracks probably exist, quite well distributed and not easily detected. 3. In the third or

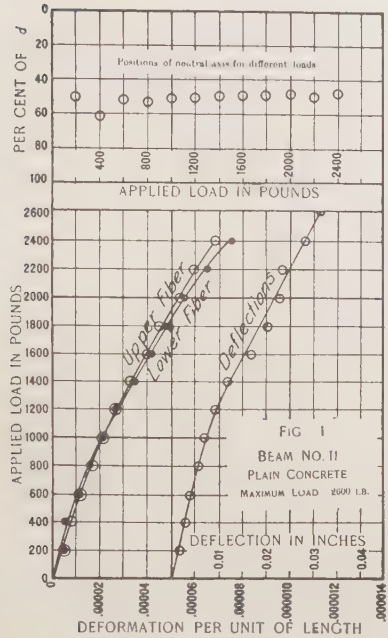
straight-line stage the neutral axis remains nearly stationary in position and the concrete gradually loses more of its tensional value. Visible cracks appear and gradually grow more distinct though no change in the character of the load-deformation diagram results. It would seem probable that at these cracks the stress in the steel is more than is indicated by the average deformation for the full gage length. 4. In beams with the metal reinforcement small enough in amount not to develop the full compression strength of the concrete, the maximum load is reached or nearly reached when the metal is stretched to its yield point and the tensional value of the concrete is here negligible except with light reinforcement, and the load at the yield point of the metal may well be considered the full strength of the beam. The later crushing of the concrete at a smaller load is the effect of the rapid stretch of the steel. 5. So far as strength of the beam is concerned, the load when the steel is stressed to its elastic limit seems the proper basis for the factor of safety and working load. 6. So far as strength of beam is concerned, steel having a high elastic limit is advantageous, it being assumed that there is sufficient provision against the slipping of rods and shearing failures. 7. The determination of the limit of reinforcement which may properly be used with different mixtures and grades of concrete may best be decided by experiments on beams made to determine this. For the 1–3–6 concrete used, reinforcement as high as $1\frac{1}{2}$ per cent for steel of 33,000 pounds per square inch elastic limit and 1 per cent for steel of 55,000 pounds per square inch elastic limit may be used without developing the full compression strength of the concrete. 8. With those beams having sufficient metal to develop the full compression strength of the concrete, the calculated resisting moment of the steel and concrete is in excess of the applied bending moment, which indicates perhaps that the center of gravity of the compressive stresses is much lower than when the compressive stress is well below this limit. 9. There was no marked difference in results found for the different forms of reinforcing bars used. It is assumed here that the beams are subject to simple flexure and that provision is made against shearing stresses and slipping of bars. The assumption that incased steel acts with the same coefficient of elasticity as naked steel has not been established and may not be true. However, the yield point of the metal is

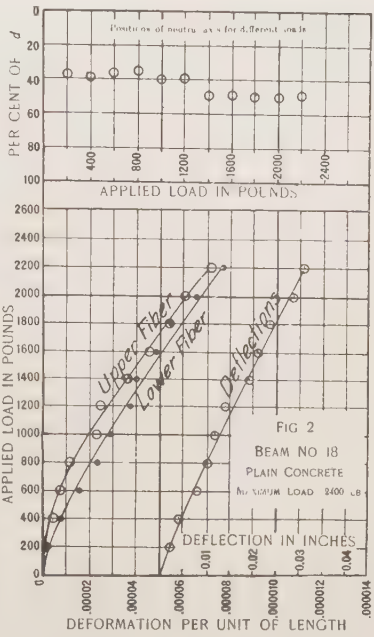
closely shown by the load-deformation curves. It should be added that experiments like these here described show the necessity for a full experimental investigation of reinforced concrete.

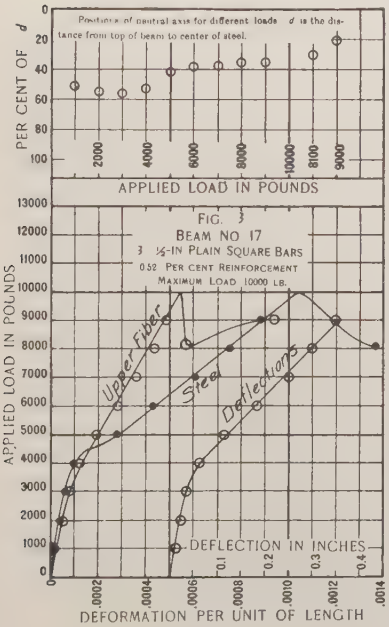
The University of Illinois purposes issuing a bulletin giving the results of these tests in detail, and plans are being made for extending the investigation. It should be said that the work of making these tests was done principally as thesis work, and that Messrs. R. V. Engstrom, F. E. Mills, S. D. Brown and R. J. Blackburn, of the Class of 1904, are entitled to credit for the care, thoroughness and untiring interest given to the investigation, and are to be commended for their skill and thoughtfulness.

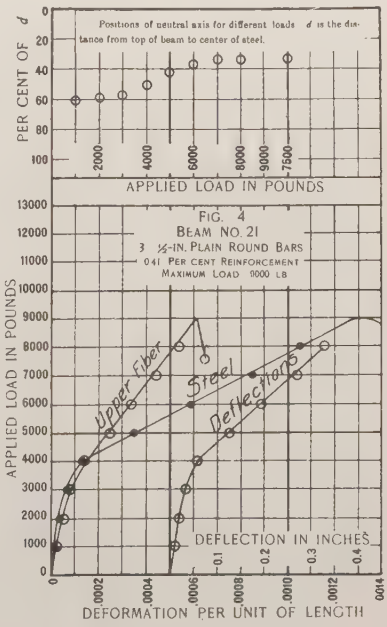
TABLE OF TESTS OF REINFORCED CONCRETE BEAMS.

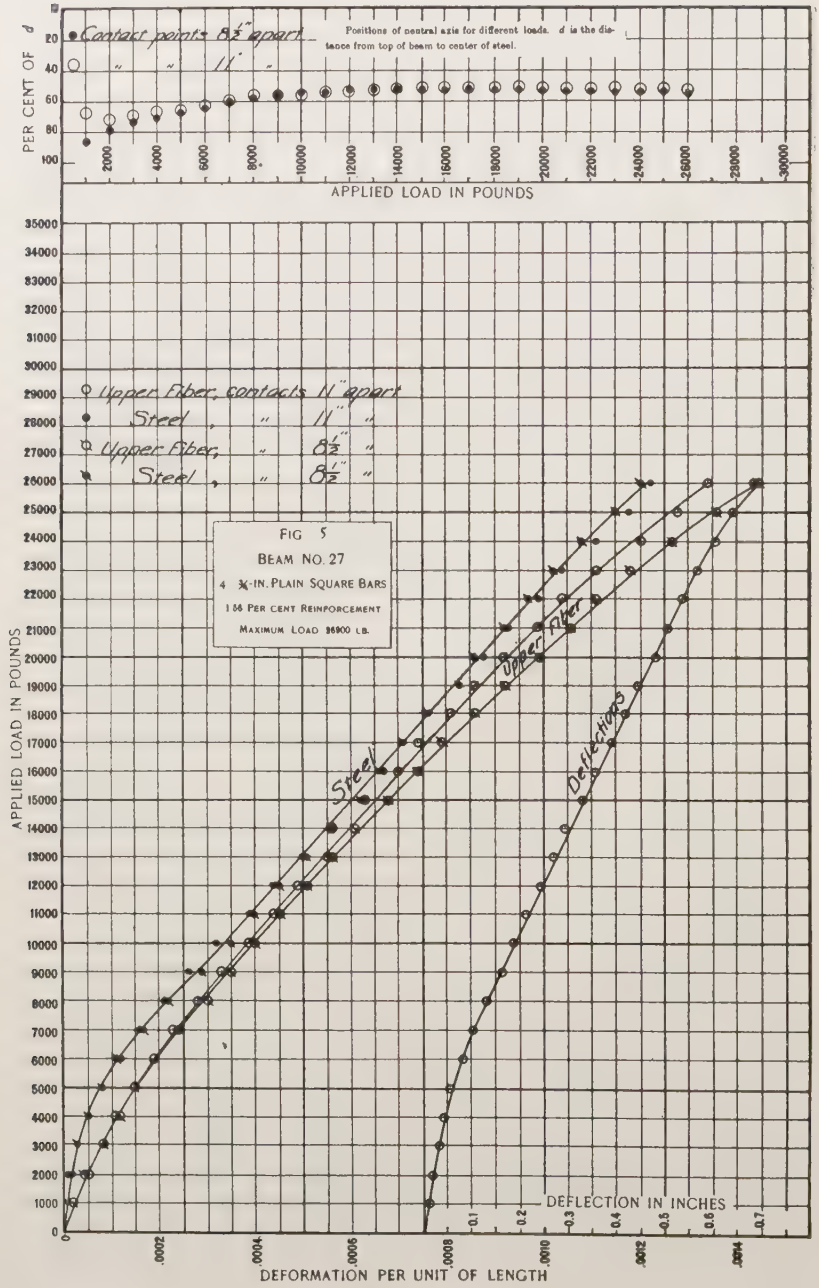
Beam No.	Amount and Kind of Reinforcement.	Area of Metal. Sq. In.	Extensometer Gage Length. Inches.	Maximum Load. Pounds.	Load Considered. Pounds.	Total Elongation of Steel for Load Considered. Inches.	Stress in Steel. Lbs. per Sq. In.	m. Inches.	Moment Arm $d-\frac{1}{11}m$ Inches.	Resisting Moment M_R In.-lbs.	Bending Moment M_B In.-lbs.	$\frac{M_R}{M_B}$	Estimated Total Bending Moment M_{B^1} In.-lbs.	$\frac{M_R}{M_{B^1}}$
21	3 ½-inch plain round	.59	60.5	9,000	8,000	.0665	32,900	4.00	10.55	204,000	224,000	.91	261,000	.78
19	3 ½- " " "	.59	60.5	9,200	9,200	.0755	37,400	4.50	10.36	228,000	257,600	.885	294,600	.775
16	3 ½- " plain square	.75	60.75	9,900	9,900	.065	32,100	4.50	10.36	250,000	277,200	.90	313,200	.80
17	3 ½- " " "	.75	60.5	10,000	9,500	.059	29,300	4.25	10.45	229,000	266,000	.86	302,000	.76
27	4 ¾- " " "	2.25	56.75	26,900	25,000	.066	34,900	6.38	9.68	760,000	700,000	1.085	725,500	1.05
9	3 ½- " Ransome .	.75	60.87	22,800	18,000	.142	70,000	3.75	10.64	559,000	504,000	1.11	540,000	1.035
15	3 ¾- " Thacher.	1.20	61.25	18,400	15,500	.0715	35,000	4.75	10.27	431,000	434,000	.99	466,000	.925
10	3 ¾- " "	1.20	60.87	16,600	14,500	.065	32,000	4.75	10.27	394,000	406,000	.97	438,000	.90
22	3 ¾- " Kahn.	2.40	56.75	24,400	22,000	.064	33,800	7.87	9.14	743,000	616,000	1.205	641,000	1.16
4	5 ½- " "	2.00	61.25	23,000	21,000	.069	33,800	5.62	9.96	673,000	588,000	1.14	615,000	1.095
14	4 ½- " "	1.60	61.5	17,200	17,000	.062	30,200	5.50	10.00	483,000	476,000	1.015	505,500	.955
5	3 ½- " "	1.20	61.25	15,000	13,000	.0625	30 600	5.00	10.18	374,000	364,000	1.03	396,000	.945
28	6 ¾- " Johnson.	2.19	60.25	34,300	31,000	.101	50,300	7.25	9.36	1,030,000	868,000	1.185	893,500	1.15
13	7 ½- " "	1.40	60.62	29,000	27,500	.111	54,100	5.75	9.91	751,000	770,000	.975	800,500	.94
20	5 ½- " "	1.00	60.75	20,900	20,000	.132	65,200	5.50	10.00	652,000	560,000	1.165	593,500	1.10
2	5 ½- " "	1.00	60.75	20,600	19,000	.119	58,800	4.75	10.27	604,000	532 000	1.135	565,500	1.07
7	3 ½- " "	.60	60.5	14,000	13,000	.1175	58,300	3.75	10.64	372,000	364,000	1.02	401,000	.925
3	3 ½- " "	.60	60.75	14,000	12,000	.1065	52,600	3.63	10.68	336,000	336,000	1.00	373,000	.90

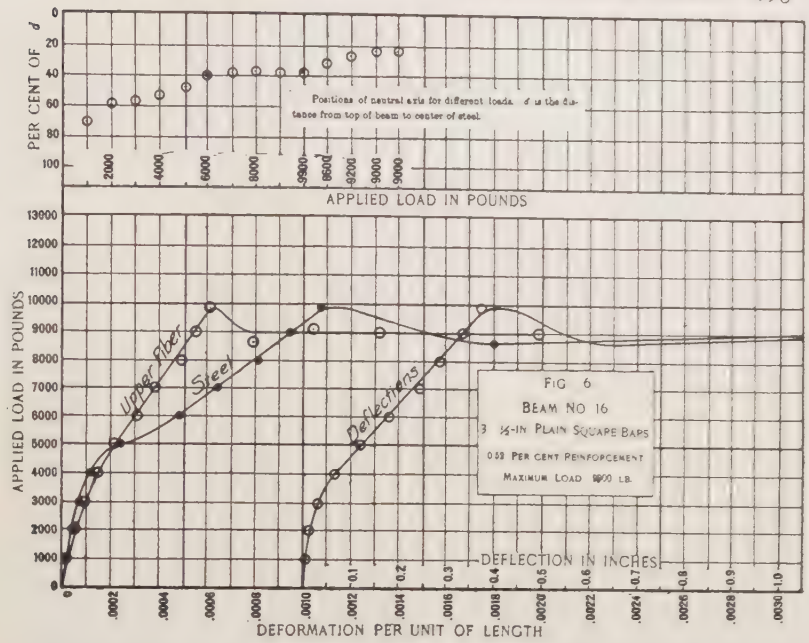

Positions of neutral axis for different loads
PER CENT OF d
APPLIED LOAD IN POUNDS
Upper Fiber
Lower Fiber
Deflections
FIG 1
BEAM NO. 11
PLAIN CONCRETE
MAXIMUM LOAD 2600 LB.
DEFLECTION IN INCHES
DEFORMATION PER UNIT OF LENGTH

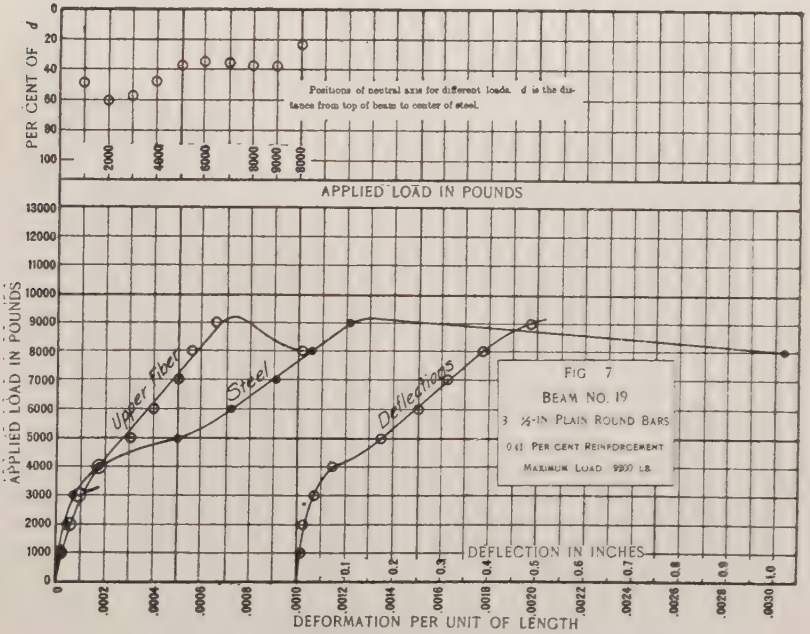

PER CENT OF d
APPLIED LOAD IN POUNDS
Upper Fiber
Lower Fiber
Deflections
FIG 2
BEAM NO 18
PLAIN CONCRETE
DEFLECTION IN INCHES
DEFORMATION PER UNIT OF LENGTH

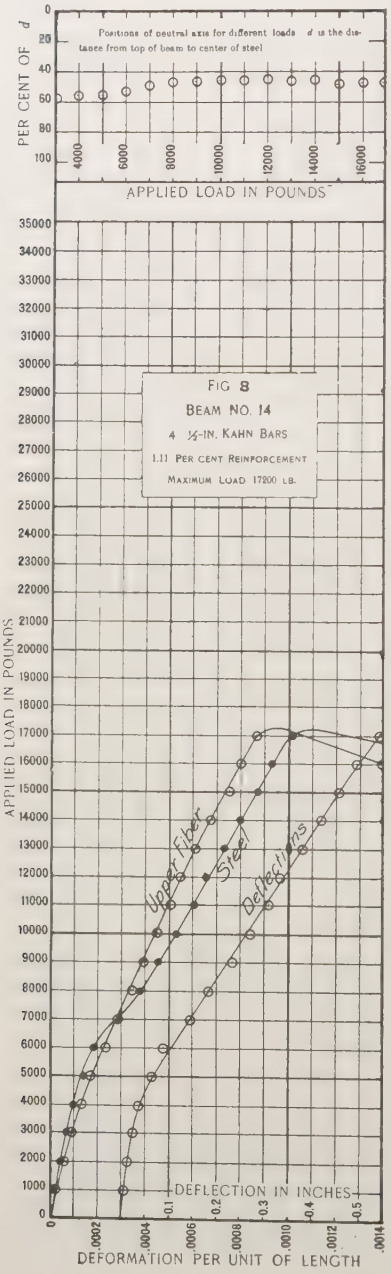

Positions of neutral axis for different loads d is the distance from top of beam to center of steel.
PER CENT OF d
APPLIED LOAD IN POUNDS
FIG. 3
BEAM NO 17
3 ½-IN PLAIN SQUARE BARS
0.52 PER CENT REINFORCEMENT
MAXIMUM LOAD 10000 LB.
Upper Fiber
Steel
Deflections
DEFLECTION IN INCHES
DEFORMATION PER UNIT OF LENGTH

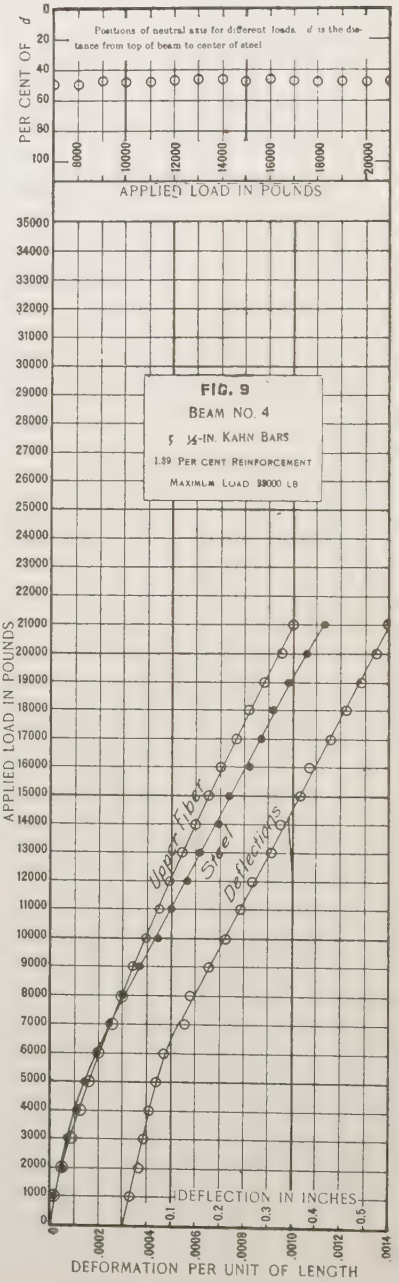

Positions of neutral axis for different loads d is the distance from top of beam to center of steel.
PER CENT OF d
APPLIED LOAD IN POUNDS
FIG. 4
BEAM NO. 21
3 ½-IN. PLAIN ROUND BARS
0.41 PER CENT REINFORCEMENT
MAXIMUM LOAD 9000 LB
Upper Fiber
Steel
Deflections
DEFLECTION IN INCHES
DEFORMATION PER UNIT OF LENGTH

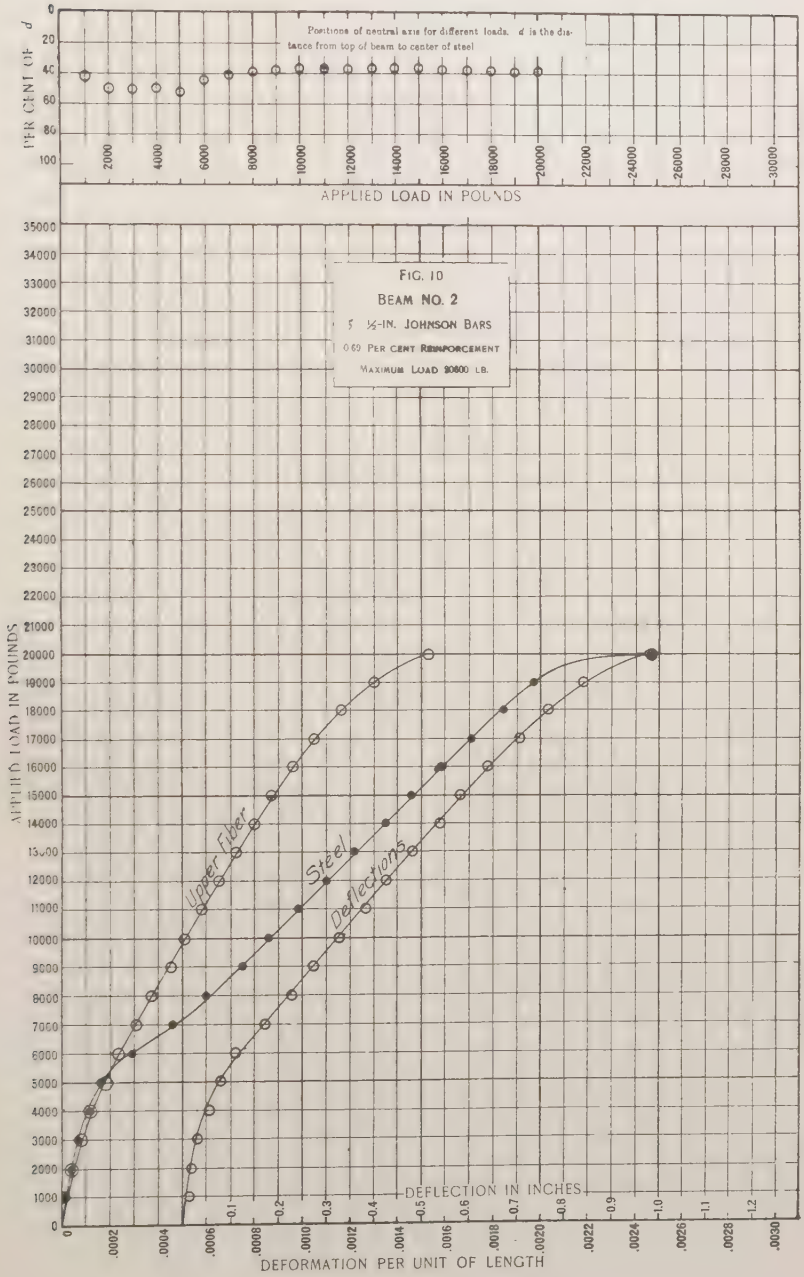

Contact points 8½" apart
" " " 11" "
Positions of neutral axis for different loads. d is the distance from top of beam to center of steel.
PER CENT OF d
APPLIED LOAD IN POUNDS
Upper Fiber, contacts 11" apart
Steel " " 11" "
Upper Fiber, " 8½" "
Steel " " 8½" "
FIG 5
BEAM NO. 27
4 ¾-IN. PLAIN SQUARE BARS
1.86 PER CENT REINFORCEMENT
MAXIMUM LOAD 26900 LB.
Steel
Upper Fiber
Deflections
APPLIED LOAD IN POUNDS
DEFLECTION IN INCHES
DEFORMATION PER UNIT OF LENGTH

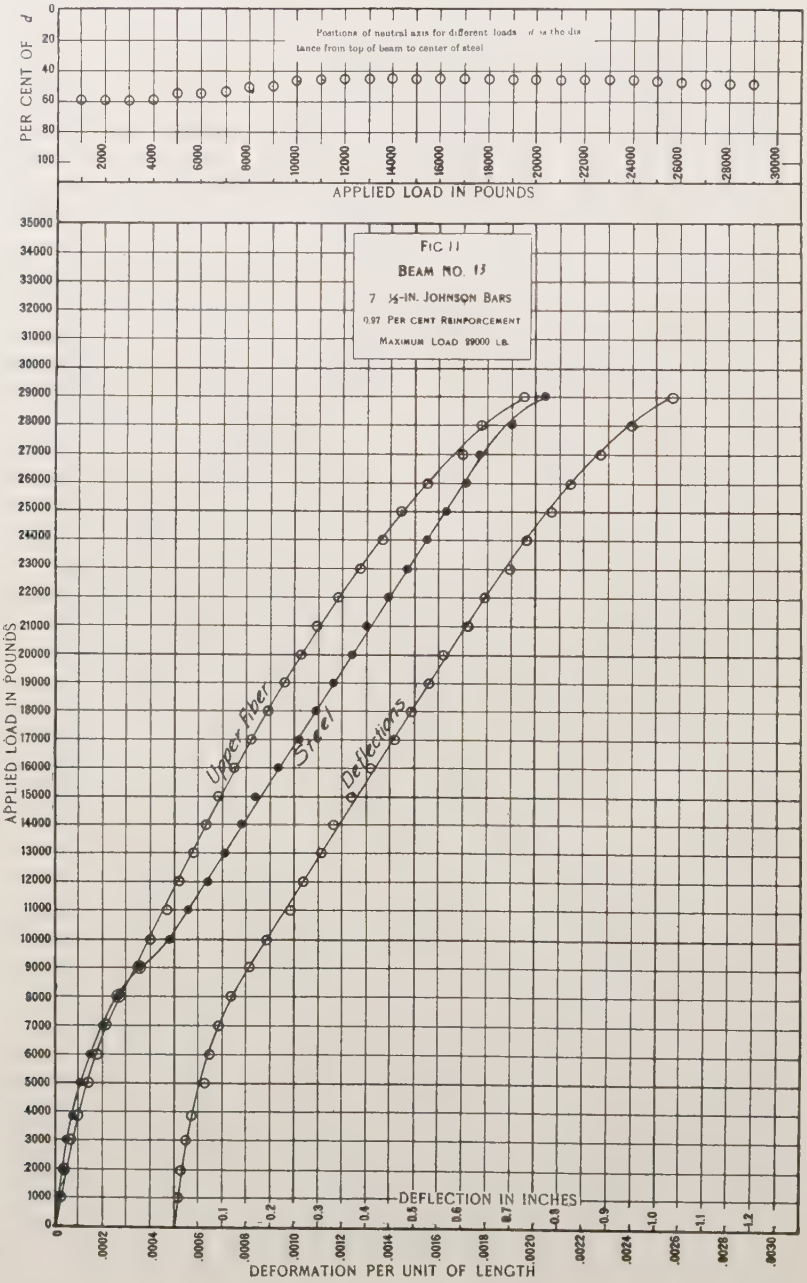

PER CENT OF d
Positions of neutral axis for different loads. d is the distance from top of beam to center of steel.
APPLIED LOAD IN POUNDS
APPLIED LOAD IN POUNDS
Upper fiber
Steel
Deflections
FIG 6
BEAM NO 16
3 ½-IN PLAIN SQUARE BARS
0.53 PER CENT REINFORCEMENT
MAXIMUM LOAD 9800 LB.
DEFLECTION IN INCHES
DEFORMATION PER UNIT OF LENGTH

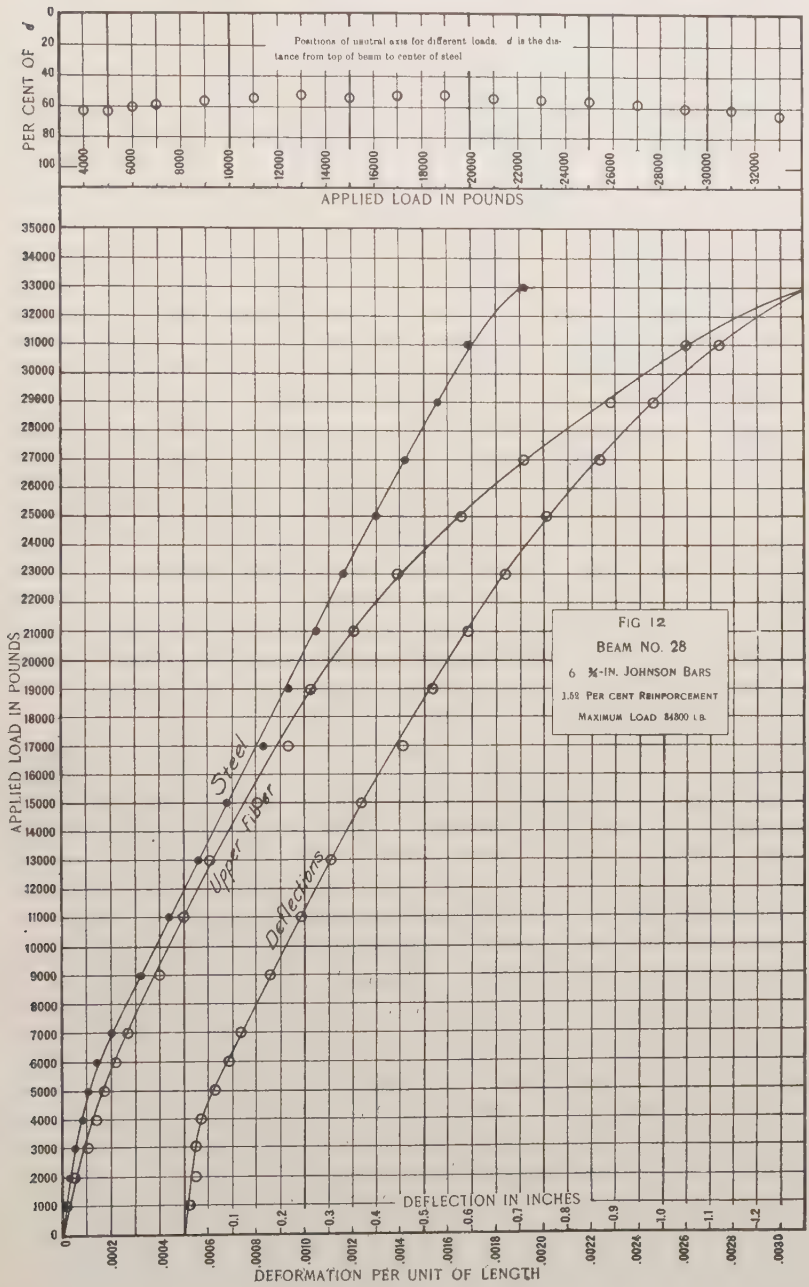

PER CENT OF d
Positions of neutral axis for different loads. d is the distance from top of beam to center of steel.
APPLIED LOAD IN POUNDS
APPLIED LOAD IN POUNDS
Upper fiber
Steel
Deflections
FIG 7
BEAM NO. 19
3 ½-IN PLAIN ROUND BARS
0.41 PER CENT REINFORCEMENT
MAXIMUM LOAD 9200 LB.
DEFLECTION IN INCHES
DEFORMATION PER UNIT OF LENGTH


Positions of neutral axis for different loads. d is the distance from top of beam to center of steel
PER CENT OF d
APPLIED LOAD IN POUNDS
FIG 8
BEAM NO. 14
4 ½-IN. KAHN BARS
1.11 PER CENT REINFORCEMENT
MAXIMUM LOAD 17200 LB.
APPLIED LOAD IN POUNDS
Upper Fiber
Steel
Deflections
DEFLECTION IN INCHES
DEFORMATION PER UNIT OF LENGTH


Positions of neutral axis for different loads. d is the distance from top of beam to center of steel
PER CENT OF d
APPLIED LOAD IN POUNDS
FIG. 9
BEAM NO. 4
5 ½-IN. KAHN BARS
1.39 PER CENT REINFORCEMENT
MAXIMUM LOAD 20000 LB
APPLIED LOAD IN POUNDS
Upper Fiber
Steel
Deflections
DEFLECTION IN INCHES
DEFORMATION PER UNIT OF LENGTH


Positions of neutral axis for different loads. d is the distance from top of beam to center of steel
PER CENT OF d
APPLIED LOAD IN POUNDS
FIG. 10
BEAM NO. 2
5 ½-IN. JOHNSON BARS
0.69 PER CENT REINFORCEMENT
MAXIMUM LOAD 20800 LB.
Upper Fiber
Steel
Deflections
APPLIED LOAD IN POUNDS
DEFLECTION IN INCHES
DEFORMATION PER UNIT OF LENGTH


Positions of neutral axis for different loads
PER CENT OF d
APPLIED LOAD IN POUNDS
FIG 11
BEAM NO. 15
7 ½-IN. JOHNSON BARS
0.97 PER CENT REINFORCEMENT
MAXIMUM LOAD 29000 LB.
Upper Fiber
Steel
Deflections
APPLIED LOAD IN POUNDS
DEFLECTION IN INCHES
DEFORMATION PER UNIT OF LENGTH


Positions of neutral axis for different loads. d is the distance from top of beam to center of steel
PER CENT OF d
APPLIED LOAD IN POUNDS
APPLIED LOAD IN POUNDS
Steel
Upper Fiber
Deflections
DEFLECTION IN INCHES
DEFORMATION PER UNIT OF LENGTH
FIG 12
BEAM NO. 28
6 ¾-IN. JOHNSON BARS
1.52 PER CENT REINFORCEMENT
MAXIMUM LOAD 34800 LB.

TESTS ON REINFORCED CONCRETE BEAMS.

By F. E. Turneaure.

Scope and Object of the Tests.—During the year 1902–3 a series of experiments on reinforced concrete beams were made in the laboratory of the University of Wisconsin, from which the most important result obtained related to the early appearance of cracks in the concrete. To verify these results and to carry on studies in other directions a second series of tests were made during the past winter. These were conducted under the direction of the author by Messrs. J. M. Gilman and G. E. Kahn as a thesis.

It has not been possible to work up the data of these tests completely for this paper, but it has been thought worth while to present the results as far as they concern: (1) the early cracking of the concrete; (2) the position of the neutral axis at different stages of the test; and (3) general results as to strength of beams reinforced by different methods and loaded in different ways.

Description of Test Beams.—Table No. 1 gives a comprehensive statement of the character of the principal test beams. The concrete, as noted, was a 1-2-4 mixture, all ingredients being proportioned by weight. Vulcanite cement was used, good coarse sand, and a crushed limestone of $\frac{3}{4}$-inch size and smaller, the very fine dust being screened out. Enough water was used to make the mass easily put in place with a very small amount of tamping. All these beams were 6 by 6 inches in section and about 64 inches long (span length 60 inches). The rods were spaced from $\frac{3}{4}$ to 1 inch from the bottom. Where bent rods were used the bend occurred 10 inches from the center, beyond which point the rod was carried up to within $\frac{3}{4}$ inch from the top of the beam at the support. Stirrups were made of 3-16 inch round rods and spaced in pairs 3 inches apart except at the center, where for a distance of 12 inches no stirrups were used.

All beams were left in the molds for 48 hours, during which time they were covered with wet cloths. After removing from the molds they were stored in running water at a temperature of about

60° F. until about four hours before testing. The particular object of thus storing the beams was to enable minute cracks to be more readily detected, in accordance with our experience of the previous year.

Compressive Strength of Concrete.—Compressive tests were made of cubes of each batch of concrete used. Three-inch cubes were tested generally, and additional four-inch cubes in some

TABLE I.

ALL BEAMS OF 1–2–4 CONCRETE. 6″ x 6″ x 60″ SPAN.

No. of Beam.	Kind of Rods.	Size of Rods.	No. of Rods.	Method of Reinforcing.	Per Cent Reinf.
1–4	No rods.				0
5–8	Plain round.	⅜ inch.	4	Straight	1.07
9–12	"	½ "	2	"	0.97
13–16	"	⅜ "	4	2 straight and 2 bent up	1.07
17–20	"	⅜ "	4	All straight, with stirrups	1.07
21–24	"	⅜ "	4	2 straight and 2 bent, with stirrups	1.07
25–28	Johnson	½ "	2	Straight	.89
29–32	Ransome	7/16 "	2	"	0.98
33–36	Thatcher	½ "	2	"	0.97
37–40	Plain round.	⅜ "	4	All straight, with stirrups	1.07

cases. The results as to strength are given in Table III. The measurements of distortion proved very unsatisfactory, so no values of the modulus of elasticity can be given.

Tests of the Steel Used.—Table II gives results of tensile tests on the different kinds of steel used. The elastic limit was determined by the "Drop of the Beam" checked by the use of dividers on the test specimen. A plain bar was purposely selected of a very high elastic limit.

Apparatus and Methods of Testing.—About one-half of the beams were tested with a center load and one-half with two equal concentrated loads placed at the third-points, thus giving a uniform bending moment over a length of 20 inches. The beams tested by the first method were one-month beams, those tested by the other method were three-month beams. All beams were tested with the tension side uppermost in order that observations for cracks could be readily made.

In both series the central deflection was carefully observed by micrometer measurements on both sides of the beam. In the second series measurements were also made of longitudinal deformations at top and bottom over a length of 14 inches. The apparatus for the latter purpose was specially constructed. It consists of two sets of frames clamped against the sides of the beam, one set carrying four graduated dials with pivoted pointers. Very fine copper wires are made fast to posts on the other frames and led over small pulleys attached to the pointers. Small weights

TABLE II.

TENSION TESTS OF STEEL.

Kind of Rod.	Nominal Size.	Elastic Limit.	Ultimate Strength.	Elongation Per Cent.
Plain round	$\frac{3}{8}$ inch.	75,000	105,000	19.4
" "	$\frac{1}{2}$ "	75,000	93,000	17.0
Thatcher	$\frac{1}{2}$ "	45,000	62,000	16.2
Johnson	$\frac{1}{2}$ "	59,000	92,500	18.7
Ransome	$\frac{7}{16}$ "	73,000	88,500	10.0

serve to keep the wires taut and to furnish the necessary friction to operate the pointers. The dials are graduated to read 0.001 inch directly and 0.0002 inch by estimation. Distortions are thus measured on four lines. This apparatus proved very satisfactory and was entirely reliable.

Careful observations for cracks were made and our experience of the previous year enabled them to be detected at a very early stage. It had been found by testing the beams when somewhat moist a crack is made visible when exceedingly small, it appearing first as a narrow, wet streak perhaps $\frac{1}{8}$ inch wide, and a little later as a dark hair-like crack. It was not necessary to search for the lines with a microscope, as under these conditions they were readily found.

That the wet streak, called a "water-mark" hereafter, shows the presence of an actual crack was demonstrated last year by sawing out a strip of the concrete containing such a crack. The strip fell apart at the water-mark.

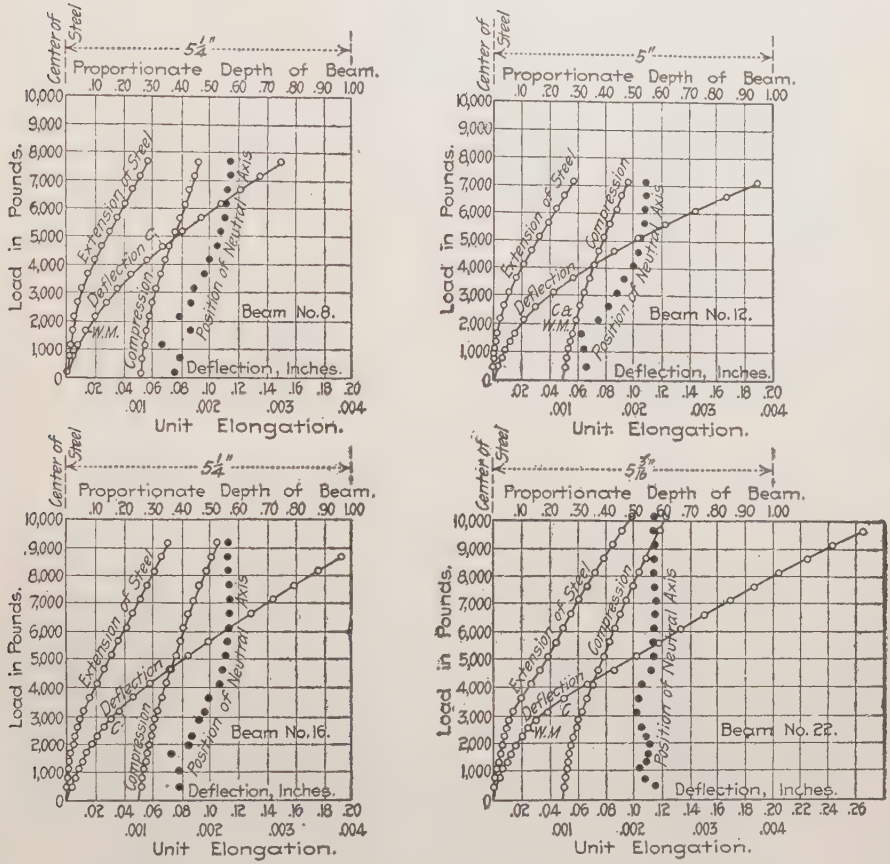


DIAGRAM SHOWING RESULTS OF TESTS OF REINFORCED CONCRETE BEAMS.

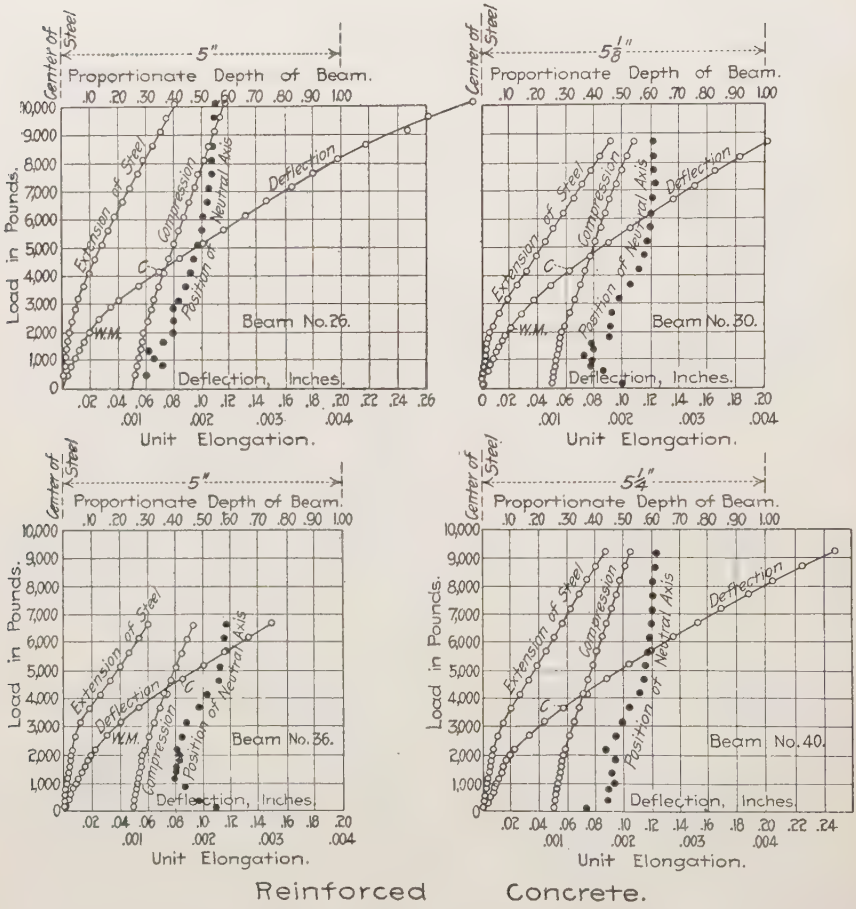
Curves of Deflections, Elongations, and Position of Neutral Axis.

NOTE.—Deflections and elongations are referred to the scales at bottom of diagrams. Position of neutral axis is referred to the scale at top of diagram.

All beams, 6x6 in., by 60 in. span, tested at three months. The above beams were reinforced with plain round rods.

W M indicates the point where the first "water-mark" was observed.

C indicates the point at which the first crack was observed.



Reinforced Concrete.

DIAGRAM SHOWING RESULTS OF TESTS OF REINFORCED CONCRETE BEAMS.

Curves of Deflections, Elongations, and Position of Neutral Axis,

NOTE.—Deflections and elongations are referred to the scales at bottom of diagrams. Position of neutral axis is referred to the scale at top of diagram.

Beam 26 reinforced with Johnson bars. Beam 36 reinforced with Thacher bars.

Beam 30 reinforced with Ransome bars. Beam 40 reinforced with plain round rods.

W M indicates the point where the first "water-mark" was observed.

C indicates the point at which the first crack was observed.

Results of the Tests.—Table No. III and the several diagrams* give the principal results of the tests. In Table No. III (a) are given the loads at rupture and the observed extensions of the extreme fiber of the concrete at the appearance of the first water-mark and also at the time when the first crack became plainly visible as a crack. The compressive strength of the concrete is given as determined from the average of the tests. In Table III (b) is given the same information, excepting that the extensions are here calculated from the deflections, assuming the form of curve of

TABLE III (a).

THREE-MONTH BEAMS. (DOUBLE LOADS.)

No. of Beam.	Load at Rupture.	Proportionate Extensions as Measured.		Compressive Strength of Concrete.
		At First Water Mark.	At First Crack.	
8 P	7,700	.00011	.00064	4,250
12 P	7,700	.00034	.00034	2,500
10 P	7,900	.00024	.00046	
14 P	10,200 a	.....	.00056	2,800
16 P	10,700	.....	.00032	
22 P	10,200	.00025	.00065	2.775
24 P	9,200	.00018	.00048	
26 J	10,200	.00016	.00056	3,000
28 J	8,700	.00013	.00040	
30 R	9,700	.00012	.00064	2,600
32 R	9,360	.....	.00050	
36 T	7,400	.00028	.00090	3,850
34 T	7,340	.00025	.00050	
38 P	13,100	.....	.00066	3,850
40 P	9,580	.....	.00050	

the beam to be the same as in the usual theory of flexure and the neutral axis to be in the center of the beam at this stage of the test. In the diagrams are plotted the deflections, the proportionate extension of the steel and compression of the extreme compressive fiber, and the deduced location of the neutral axis assuming plane sections, for one beam of each kind tested. The appearance of the first water-mark and of the first crack are also noted on the deflection curves.

* Acknowledgment is made to the *Engineering News* for the cuts used in this paper.—ED.

It will be noted from these tables that the elongation of the concrete at the time of the first visible crack is in many cases as small as 0.00035 inch., which is considerably less than that given by previous observers. And if we take the water-mark as indicating the presence of a crack not yet visible the elongation of the concrete is seen to be usually between 0.00010 and 0.00020 inch.

The calculated elongations of Table III (b) are subject to

TABLE III (b).

ONE-MONTH BEAMS. (CENTER LOADS.)

No. of Beam.	Load at Rupture.	Proportionate Elongation as Calculated.		Compressive Strength of Concrete
		At First Water Mark.	At First Crack.	
2*	1,000	.....	.00013	3,000
4*	900	.....	.00011	
3	800	.....	.00014	2,500
1	800	.....	.00010	
7 P	8,100	.00015	.00056	3,500
5 P	5,700	.00020	.00031	
11 P	5,000	.00014	.00018	2,200
9 P	5,500	.00011	.00048	
15 P	7,300	.00007	.00011	2,350
13 P	6,400	.00009	.00011	
23 P	5,500	.00020	.00060	2,500
21 P	6,250	.00027	.00049	
27 J	6,400	.00011	.00031	2,300
25 J	6,460	.00009	.00048	
29 R	8,125	.00019	.00100	2,000
31 R	7,880	.00012	.00083	
35 T	5,000	.00013	.00053	3,150
33 T	5,200	.00021	.00095	
39 P	8,250	.00023	.00053	2,740
37 P	6,700	.00010	.00033	

* Three months old.

some uncertainty, but for the early stages of the test they cannot be far wrong. A similar method of calculation applied to the three-month beams gives results agreeing very closely with the observed values up to an elongation of about 0.0003 inch. Above this the calculated values become too small owing to the change in position of the neutral axis. In general the first water-mark of Table III (b) was more carefully observed than in the tests of

Table III (a), as the extension apparatus interfered somewhat in the latter case. In the plain concrete no water-marks or cracks were observed before rupture. Comparing the observed and calculated elongations of the reinforced concrete with those for the plain concrete at rupture it will be seen that the initial cracking in the former occurs at an elongation practically the same as in the latter. It will also be noted on the diagrams that the initial cracking as shown by the water-marks usually begins about where the curves begin to change direction rapidly.

The significance of these minute cracks is an open question. It has been supposed that concrete reinforced by steel will elongate about 10 times as much before rupture as plain concrete. These experiments show very clearly that rupture begins at an elongation about the same in both cases. In the plain concrete total failure ensues at once; in the reinforced concrete rupture occurs gradually, and many small cracks may develop so that the total elongation at final rupture will be greater than in the plain concrete. In other words, the steel develops the full extensibility of a non-homogeneous material that otherwise would have an extension corresponding to the weakest section.

The presence of these cracks of course seriously affects the tensile strength of the concrete, and as they appear at an elongation corresponding to a stress in the steel of 5,000 pounds per square inch or less, it would seem that no allowance should be made for the tensile resistance of the concrete. Furthermore, if such cracks are present the calculation of the tensile resistance of reinforced concrete by the method used by Considère leads to no useful result. In his tests Considère determines the stress in the steel from measurements of its elongation and then assumes the concrete to carry the remainder. Assuming the value of E to be uninfluenced by the concrete, this would be correct so long as the stress in the steel and in the concrete is uniform between points of measurement. As stated by Considère himself, such results are only *average* values. But the concrete may be cracked entirely through and yet possess a very considerable *average* tensile strength over a length of several inches. Obviously in that case an average is of no value; the strength of the concrete is really zero.

In practical design the most important question which arises is how far a concrete may be cracked without exposing the steel to

corrosive influences. In this respect it seems to the writer that the minute cracks which appear in the early stages of the tests can have very little influence. However, the entire question of the effect of cracks and pores in the concrete on the corrosion of the steel needs careful investigation.

The Position of the Neutral Axis.—The diagrams show the neutral axis to lie at first very near the center of the concrete beam. As the cracks develop it moves gradually nearer to compression side. It should be noted that the neutral axis as here found, by

TABLE IV.

MOMENTS OF RESISTANCE OF BEAMS.

Beam.	Actual Moment of Resistance. Inch-Pounds.	Area of Steel. Square Inches.	Calculated Stress in Steel. Pounds Per Square Inch.
5.7	104,000	.385	61,000
.8	77,000		46,000
9.11	79,000	.35	52,000
10.12	78,000		52,000
13.15	103,000	.385	61,000
14.16	104,000		61,000
21.23	88,000	.385	52,000
22.24	97,000		57,000
25.27 J	96,000	.32	70,000
26.28 J	95,000		70,000
29.31 R	120,000	.35	78,000
30.32 R	95,000		62,000
33.35 T	77,000	.35	52,000
34.36 T	74,000		50.000
37.39 P	112,000	.385	65,000
38.40 P	113,000		65,000

measuring deformations over a length of 14 inches, is the *average* neutral axis over this distance. Where a crack exists the elongation per inch of the steel is more than elsewhere, and the neutral axis is therefore nearer the compression side than is the average position.

Ultimate Strength of the Beams.—In Table IV are given the ultimate moments of resistance of the beams and the resulting stress on the steel as determined by calculation. In this calculation the center of pressure of the concrete is assumed to be five-eighths of the distance from the observed neutral axis to the outside surface,

corresponding to a parabolic variation of compressive stress. (The assumption of a straight line variation would change the calculated values only about 2 per cent.) The average of the two results for the one-month beams is given first in each group and that for the three-month beam just below. These calculations indicate that the full elastic limit strength of the Johnson and the Thatcher bars was developed and probably of one or more of the Ransome bars, but that in the other cases failure occurred before the elastic limit was reached.

The stresses in the bars as here calculated, and which cannot be greatly in error, will be seen to be in nearly every case much higher than would be deduced from the observed elongations of the steel as given in the diagrams, using the usual modulus of elasticity. Thus in the case of beam No. 12 the elongation at rupture was 0.00115 inch. Assuming a value of E of 29,000,000, the stress would be 33,000 pounds per square inch, whereas the calculations from the actual moment give a stress of 53,000 pounds. The discrepancy is doubtless due partly to the fact that the calculations from the elongations cannot give the maximum stress on the rods, but it is impossible that all of the difference can be accounted for in this way. There must have been a large initial tension in the rods which of course would not be indicated by the extensometer readings. As the beams were hardened in water such initial tension is very probable.

In but a few cases was the failure free from the influence of shearing stresses, the rupture usually occurring outside the load and on a diagonal line. In a few cases, after the cracks had opened up well, the concrete failed in compression. The maximum compressive stress in the concrete, calculated on the assumption of a parabolic law, ranged from 2,100 pounds per square inch for the weakest beam to 3,000 pounds per square inch for the strongest. No trouble was experienced from the slipping of the rods, except in one case where they had become displaced in the molding.

TESTS OF REINFORCED CONCRETE BEAMS.

By Edgar Marburg.

A series of tests on reinforced concrete beams has just been completed in the testing laboratory of the Civil Engineering Department of the University of Pennsylvania. These tests were made the subject of a joint thesis on the part of four members of the Senior Class, Messrs. George Freeman, Jr., Thomas Hovenden, H. M. Peirson, and A. C. Toner. The programme was planned and executed under the direction of the writer.

Scope of Tests.—The beams were made and tested under conditions as nearly identical as practicable in every respect, except span and character of reinforcement. Twenty-five 8 x 8-inch beams of 1-2-4 broken-stone concrete were tested at the age of 30 days under central loading—twelve on an 8-foot span, thirteen on a 5-foot span. The lengths out to out were 8.5 and 5.5 feet. The concrete was both plain and reinforced, the reinforcement consisting of plain square rods, and rods of the Johnson, Ransome and Thacher types. The rods were nominally $\frac{1}{2}$ inch square, although the actual net sections varied from 0.18 to 0.255 square inch for the various types. Three rods were imbedded in each beam with centers 1 inch from the bottom surface. Laterally the two side rods were centered $2\frac{2}{3}$ inches from the middle rod. The percentage of metal to the total cross-section varied from 0.84 to 1.19 per cent. Various collateral tests were made to which further reference will be had hereafter. The specimens for these tests were all of the same composition as the beams and were tested at the same age, 30 days.

Materials.—The cement used was Atlas Portland, purchased on the open market. The tensile strength, neat, in pounds per square inch, was 337 at 1 day, 629 at 7 days, and 793 lbs. per sq. in. at 30 days, each value being the average of six tests. The mean departure from the average value was 3.8, 4.5 and 3.4 per cent, respectively, for the three sets. The determination of fineness showed the following residues: On No. 50 sieve, 0.5 per cent; on No. 100 sieve, 4.8 per cent; on No. 200 sieve, 22.4 per

cent. The time of initial set, determined by means of the Vicat needle, ranged from 23 to 25 minutes for three observations. Pat tests in air and water gave normal indications.

The stone was ¾-inch trap-rock from Glen Mills, Pa., and gave the following residues: On sieve of ¾-inch mesh, 0.64 per cent; on sieve of ½-inch mesh, 35.5 per cent; on No. 6 sieve, 92.5 per cent.

The sand used was a good quality bar sand from the bed of the Delaware River at Bordentown, N. J., and gave the following residues: On No. 20 sieve, 2.8 per cent; on No. 30 sieve, 11.8 per cent; on No. 50 sieve, 59.6 per cent.

Mixing and Molding.—The materials used for the concrete were proportioned by measure: 1 part of sand to 2 parts of cement and 4 parts of broken stone. To avoid variations in the quantities of cement due to differences in the degree of compacting, the standard volume was weighed and the quantities were afterwards determined by weight. The cement and sand were thoroughly mixed dry by shovel to an even color, and 16 per cent (of their combined weight) of water was then added. The mortar was turned until it was of uniform consistency, and the broken stone, previously dampened, added. The concrete was turned until the stones were thoroughly coated with the mortar. The concrete was rammed into the molds by means of a 27.5-pound rammer with a flat bottom face 6 x 8½ inches. Great care was taken to insure accuracy in placing the rods. The thickness of the bottom layer was fixed by means of a template. The rods were then introduced, concrete added, and gently tamped, more concrete added and thoroughly rammed as above described.

The water rose freely to the top during ramming. A wet mixture was chosen to insure solidity and uniformity of the concrete, and the adhesion of the imbedded rods. No voids appeared in the fractured surfaces of any of the broken specimens, and the bond between the rods and the concrete was continuous and apparently perfect.

The specimens were stored in the laboratory at a temperature of about 70° F. The 8-foot beams were left in the molds for about a week, the 5-foot beams for about three days. No measures were taken to keep the surfaces damp during hardening, and no visible shrinkage cracks developed. The weight of the concrete was about 154 lbs. per cu. ft.

Wooden molds of two types were used. The one hinged longitudinally along a central line at the bottom, the other with one removable side-piece. The latter proved more convenient. In both types the end-pieces of the molds were detachable.

Specimens were also prepared for compression, tension and adhesion tests, which will be described in more detail hereafter.

Bending Tests.—The beams were supported at the ends on straight, rounded, steel saddles, grooved on the bottom and resting on curved, rounded bearings. The load was applied through a straight, rounded bearing at the center acting on a steel bearing block 2 inches wide and 8 inches long, flat on the bottom and having a rounded groove at the top, curved in a plane normal to the direction of the beam. Thus there was perfect freedom of adjustment at the bearings, and the influence of eccentric loading was practically eliminated.

The load was applied to the reinforced beams in increments of 500 lbs. In the case of the two unreinforced beams, the load increment was 250 lbs. for beams U_1^5, and 200 lbs. for beam U_1^8. The deflections were read at the middle of the span on both sides of the beams by means of a pair of micrometer screws reading direct to 0.0001 inch, supported in a yoke clamped to the beam in the plane of the rods. These screws made electric contact at the center of a pair of longitudinal steel bars supported by clamp screws attached to a yoke directly above the end bearings and at or about the neutral plane of the beam. These bars were pivoted at one end, and allowed to slide freely on rounded pins at the other. As a matter of fact, no such longitudinal movement could be discerned as the tests progressed. To minimize the chance of error every reading throughout these tests was made independently by two observers.

In the tables following the beams are designated by the initial letters of their reinforcement: P stands for plain rods, J for Johnson, R for Ransome, and T for Thacher rods. U indicates unreinforced beams. The exponents denote the spans in feet and the subscripts the running numbers of the tests in each individual set.

The first indications of failure were in the form of very fine hair-line cracks, transversely across the bottom of the beam for a length of one to two inches. The first to appear were 1 to 4 inches

from the center. On increasing the load others soon appeared at various points across the bottom up to 10 inches on both sides of

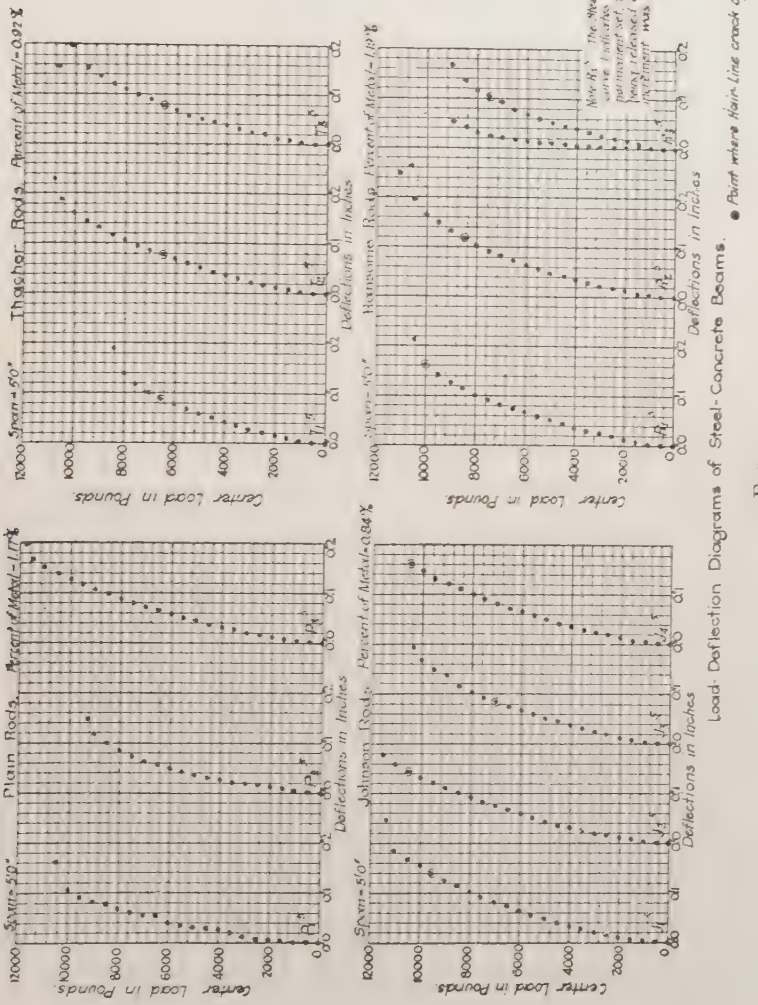

Thatcher Rods. Percent of Metal = 0.92%
Span = 5'0"
Center Load in Pounds
Deflections in Inches
Hennessy Rods. Percent of Metal = 1.29%
Span = 5'0"
Center Load in Pounds
Deflections in Inches
Note R1. The steeper curve indicates the permanent set that had been released after each increment was applied
Plain Rods. Percent of Metal = 1.17%
Span = 5'0"
Center Load in Pounds
Deflections in Inches
Johnson Rods. Percent of Metal = 0.84%
Span = 5'0"
Center Load in Pounds
Deflections in Inches
Load-Deflection Diagrams of Steel-Concrete Beams. • Point where Hair-Line crack appeared

FIG. 1.

the center. These cracks widened and lengthened for a few hundred pounds increment of loading, and then in the majority of cases remained stationary. In the case of beam R_1^8 and R_3^5, for

which the load was released after each successive application, these cracks disappeared entirely during the release of the load.

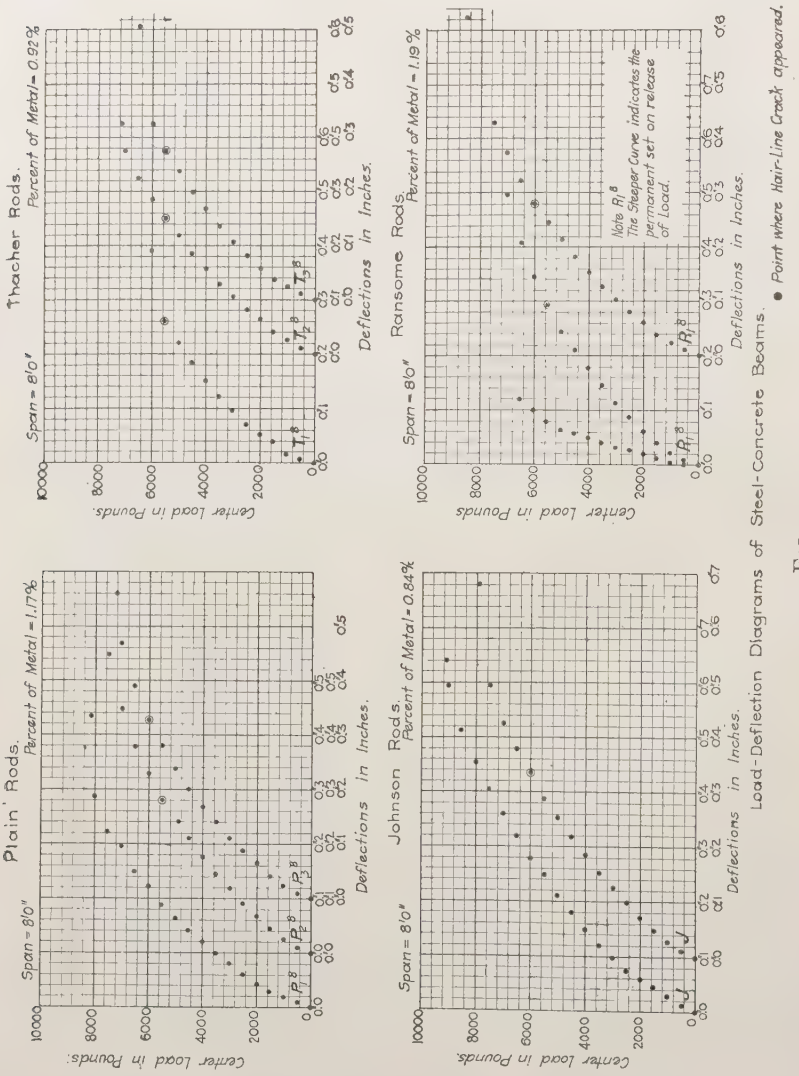

Thacher Rods.
Percent of Metal = 0.92%
Span = 8'0"
Center Load in Pounds.
Deflections in Inches.
Ransome Rods.
Percent of Metal = 1.19%
Note R1.8
The Steeper Curve indicates the permanent set on release of Load.
Plain Rods.
Percent of Metal = 1.17%
Johnson Rods.
Percent of Metal = 0.84%
• Point where Hair-Line Crack appeared.

FIG. 2.

Load-Deflection Diagrams of Steel-Concrete Beams.

Broadly speaking, final failure occurred in four different characteristic ways designated in the table by the numerals 1, 2, 3 and 4, which may be described briefly as follows:

1. By a diagonal crack starting at the plane of the rods and running up to the center at the top at a mean angle of about 30° with the horizontal.

2. By a vertical crack starting by the enlargement of a hair-line crack running across the bottom and up the sides not more than 4 inches from the center.

3. By a sudden diagonal crack from the center at the top to the end support at the bottom.

4. By crushing at the center at the top of the beam.

Failure occurred by method 1 in 12 cases, by method 2 in 7 cases, by method 3 in 2 cases, and by method 4 in 4 cases.

In case of failure by method 1 the diagonal crack developed more or less suddenly. In some cases this crack extended to the bottom of the beam and across the same. More commonly, however, it continued, from the point where it reached the plane of the upper surface of the rods, along this plane.

In the case of failure by method 4 there were also indications of failure by method 2, but the vertical cracks near the bottom ceased to develop after crushing began at the top.

The manner of failure in each case is described more minutely in Table I. In beam P_2^5 the rods slipped immediately before final failure. In beams P_1^5 and T_1^5, the adhesion between the rods and the concrete was broken by the crack along the plane of the rods. The rods in these beams slipped in consequence, but after (not before) final failure. In none of the other beams was there any longitudinal movement of the rods. Careful watch was kept on such movement by observing the ends of the rods.

The load-deflection diagrams for these beams are shown in Fig. 1 for the 5-ft. beams and in Fig. 2 for the 8-ft. beams.* In the case of beams R_1^3 and R_3^5 the load was released after each reading, and the permanent set obtained as shown in the diagrams of these beams.

TABLE I.—MANNER OF FAILURE OF BEAMS.

Number of Beam.	Method of Failure.	DESCRIPTION OF FAILURE.
P_1^5	1	Diagonal crack at bottom, 12 inches from center, running to center at top. Secondary crack running from first crack toward end in plane of rods.

*Acknowledgment is made to the *Engineering Record* for the cuts used in this paper.

TABLE I.—Continued.

Number of Beam.	Method of Failure.	DESCRIPTION OF FAILURE.
P_2^5	1	Diagonal crack at bottom, 6 inches from center, running to center at top. Rods slipped.
P_3^5	1	Diagonal crack at bottom, 15 inches from center, running to center at top. Secondary crack running from first crack toward end in plane of rods.
P_1^8	1	Diagonal crack at bottom, 11 inches from center, running to center at top, where crushing occurred.
P_2^8	4	Hair-line crack at bottom, 4 inches from center, widened and ran a short distance up side; final failure occurred by crushing of concrete at top.
P_3^8	4	Similar to P_2^8, except that hair-line crack started at center.
J_1^5	3	Hair-line cracks at bottom, 10 inches each side of center, ran up side a short distance. Final failure by sudden diagonal crack from center at top to end support.
J_2^5	3	Sudden failure by diagonal crack from center at top to end support.
J_3^5	1	Sudden failure by two diagonal cracks on same side of center, 15 and 22 inches from the center, running from plane of rods to center at top.
J_4^5	1	Sudden failure by diagonal crack 18 inches from center, running from plane of rods to center at top, and crack in plane of rods from first crack toward end.
J_1^6	4	Many hair-line cracks along bottom. Concrete crushed at top. Secondary diagonal crack.
J_2^6	1	Several hair-line cracks on sides. Diagonal failure crack 12 inches from center running from plane of rods to center at top. Irregular cracks in plane of rods.
R_1^5	1	Diagonal crack 13 inches from center, running from plane of rods to center at top.
R_2^5	1	Many hair-line cracks on bottom. After ultimate load was reached, diagonal cracks appeared 14 inches on each side of center.
R_3^5	1	Sudden failure by diagonal crack 17 inches from center, running from plane of rods to center at top. Secondary crack running from first crack toward end in plane of rods.
R_1^8	1	Irregular diagonal crack 22 inches from center at bottom to center at top. Two large cracks across bottom 15 and 17 inches from center.
R_2^8	4	Many hair-line cracks. Concrete crushed at top.
T_1^5	1	Diagonal cracks 9 inches from center on both sides at bottom toward center at top. Secondary crack running from first crack toward end in plane of rod.

TABLE I.—Continued.

Number of Beam.	Method of Failure.	DESCRIPTION OF FAILURE.
T_2^5	2	First hair-line cracks 3 inches from center increased and ran up toward center at top.
T_3^5	2	Same as T_2^5 crack, 4 inches from center.
T_1^8	2	Same as T_2^5 crack, 2 inches from center.
T_2^8	2	Same as T_2^5 crack, 4 inches from center.
T_3^8	2	Same as T_2^5 crack, 2 inches from center.
U_1^5	2	Sudden failure, by vertical crack 2 inches from center.
U_1^8	2	Sudden failure, by vertical crack, 4 inches from center.

Table II shows, (1) the loads at which the hair-line cracks were first observed; (2) the loads at which the failure crack became

TABLE II.—THE THREE CRITICAL LOADS OF EACH BEAM.

Number of beam.	Age, days.	Load at which hair-line crack was first noticed, lbs.	Load at which failure crack appeared, lbs.	Ultimate load, lbs.	Deflection at hair-line crack, in.	Deflection at failure crack in.
P_1^5	30	Not observed	10,500	10,500	Not observed	.1638
P_2^5	29	Not observed	9,290	9,290	Not observed	.1485
P_3^5	30	Not observed	11,720	11,720	Not observed	.1687
P_1^8	31	Not observed	8,000	8,125	Not observed	.3868
P_2^8	30	5,500	7,000	7,500	.2816	.4480
P_3^8	30	5,500–6,000	6,750	7,280	.2814–.3287	.4684
J_1^5	30	9,500	11,370	11,370	.1409	.1856
J_2^5	30	10,000–10,500	12,000	12,000	.1319–.1438	.1776
J_3^5	30	6,500–7,000	10,300	10,300	.0743–.0846	.1675
J_4^8	30	10,000–10,500	10,725	10,725	.1475–.1618	.1618
J_1^8	30	4,000–4,500	9,090	9,160	.1499–.1806	.6415
J_2^8	30	6,000	7,950	8,110	.3359	.4952
R_1^5	30	9,500–10,000	10,430	10,430	.1423–.1628	.1628
R_2^5	30	8,000–8,500	11,020	11,020	.1036–.1175	.1958
R_3^5	31	7,500	9,000	9,000	.1040	.1671
R_1^8	30	5,500	7,390	7,390	.2935	.4964
R_2^8	30	6,000	8,750	8,780	.2817	.6229
T_1^5	30	6,500	8,000	8,520	.0887	.1895
T_2^5	30	6,500	10,780	11,240	.0768	.2283
T_3^5	30	6,500	10,000	10,180	.0770	.1974
T_1^8	30	5,000–5,500	6,150	6,370	.2213–.2599	.3933
T_2^8	30	5,500	7,130	7,300	.2512	.4266
T_3^8	30	5,000–5,500	6,400	6,850	.2370–.2769	.5080
U_1^5....	30	.....	.....	1,230	.....	.0063
U_1^8	30	.....	.....	720	.....	.0126

clearly apparent; and (3) the ultimate loads. The deflections corresponding to the first and second loads are also given. The

hair-line cracks, which were exceedingly minute and appeared first at the bottom of the beams, escaped detection in beams P^5_1, P^5_2, P^5_3 and P^8_1 which were the first beams tested. In all of the remaining reinforced beams a careful watch was kept on the appearance of these minute fissures. In some cases they first became evident during the application of the load increments. In such cases the values of the load limits between which these cracks became noticeable, are indicated. In all such cases the deflections corresponding to both loads are recorded. It is to be observed that the beams were all tested at the age of 30 days, except beam P^5_2, which was tested at 29 days, and beams P^8_1 and R^5_3, which were tested at 31 days. The influence of the difference of a single day in the age of the three beams mentioned is regarded as negligible without sensible error.

TABLE III.—AVERAGE RESULTS OF TESTS.

Beam.	Load at hair-line crack, lbs.	Load at failure crack, lbs.	Ultimate load, lbs.	Deflection at hair-line crack, in.	Deflection at failure crack, in.
P^8	Not observed	10,500	10,500	Not observed	0.1603
J^8	9,400	11,100	11,100	0.1328	0.1731
R^8	8,700	10,150	10,150	0.1281	0.1752
T^8	6,500	9,600	10,000	0.0808	0.2051
P^5	5,750	7,250	7,650	0.3052	0.4344
J^5	5,250	8,500	8,650	0.2583	0.5684
R^5	5,750	8,100	8,100	0.2876	0.5597
T^5	5,500	6,550	6,850	0.2627	0.4426

The moduli of rupture of the two unreinforced beams, computed by the common theory of flexure, were found to be 287 and 250 pounds per square inch for the 8 and 5-foot beams, respectively, including their own weight: 600 pounds for the 8-foot and 380 pounds for the 5-foot beam.

The averages of the values in Table II for the various types of reinforcement and for the two span-lengths used, are shown in Table III. In computing these averages the higher values in columns 3 and 6 of Table II were used.

Attention has previously been called to the fact that while the rods were nominally $\frac{1}{2}$-inch square, there was actually a considerable

difference between the smallest lateral dimensions of the rods of the different types. These dimensions as well as the percentage of the metal section to the total cross-section of the beam, are given in Table IV.

TABLE IV.—AMOUNT AND PROPERTIES OF REINFORCING STEEL.

Type of rod.	Area of Metal.		Elastic limit.	Ultimate strength.	Modulus of elasticity.	Percentage of elongation in 8 in.
	Sq. in.	Percentage of cross-section.				
P	0.75	1.17	40,500	60,600	30,500,000	23.50
J	0.54	0.84	65,800	102,300	28,500,000	13.50
R	0.76	1.19	58,000	86,500	26,000,000	7.75
T	0.59	0.92	31,900	51,300	28,500,000	13.00

The values of the elastic limit in this table represent in reality the values of the yield points; that is to say, these values were fixed by the drop of the scale-beam. The values of the elastic limit were somewhat lower, as may be seen by reference to the stress-strain diagrams of these rods as plotted in Fig. 3. The deformations were determined by means of a double-micrometer extensometer reading direct to 0.0001 inch. These diagrams are plotted up to the load limits for which the extensometer was used. The reading following the highest one plotted in these diagrams showed so marked an increase in the deformation that it was evident that the yield point had been reached. This was also confirmed by the drop of the scale-beam, except in the case of the Ransome rod, in which there was no well-defined indication of a drop. Each value of the elastic limit, ultimate strength and modulus of elasticity in Table IV represents the mean of two tests, except the values of the elastic limit and modulus of elasticity of the Ransome rod, which are based on single tests. Owing to the twist of this rod it was somewhat difficult to make satisfactory determinations by means of the extensometer. The individual tests constituting each pair showed a fair agreement, especially for the softer steel. The differences were as follows: Elastic limit: P, 1,000; J, 3,900; T, 2,600 pounds. Ultimate strength: P, 400; J, 6,400; R, 8,400; T, 1,500. Elongation in 8 inches: P, 1.0; J, 1.0; R, 0.5; T, 2.0 per cent.

The moduli of elasticity showed a substantial agreement for rods of the same type, as is apparent in the diagram. It is to be

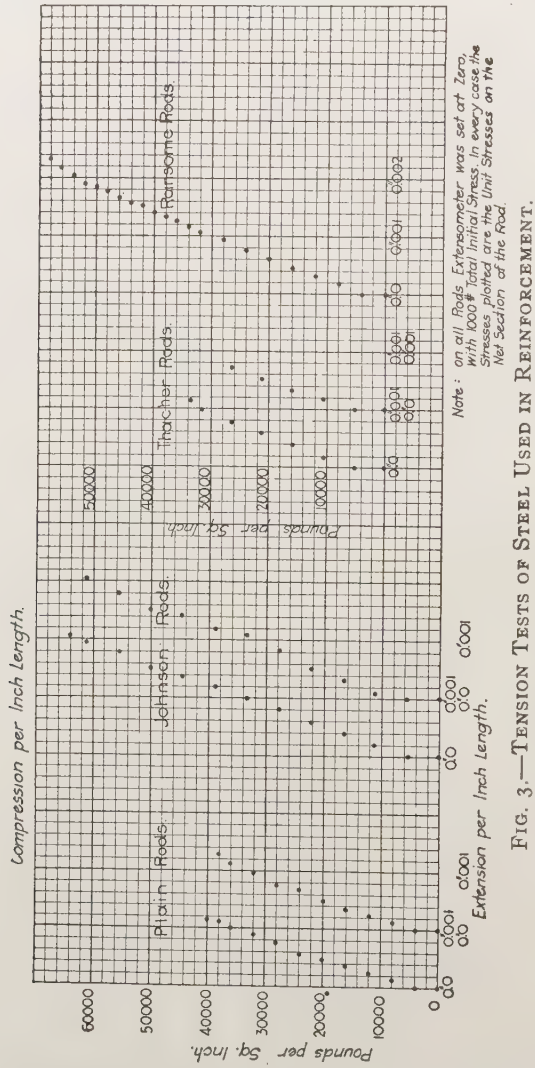

Compression per Inch Length.
Pounds per Sq. Inch.
Plain Rods.
Johnson Rods.
Thacher Rods.
Ransome Rods.
Pounds per Sq. Inch.
Extension per Inch Length.
Note: on all Rods Extensometer was set at Zero with 1000# Total Initial Stress. In every case the Stresses plotted are the Unit Stresses on the Net Section of the Rod.

FIG. 3.—TENSION TESTS OF STEEL USED IN REINFORCEMENT.

observed, however, that the values of the moduli of elasticity are based on the average unit deformations for the gauge-length of 8 inches. For the Johnson rods this is doubtless somewhat less than

the unit deformations of the smallest sections for which the unit stresses were computed; that is to say, the modulus of elasticity of the material itself in these rods is somewhat lower than indicated in the Table IV. The values of the total elongation in a gauge-length of 8 inches are shown in the last column of tho table.

Two of the beams reinforced by Thacher rods (T_3^5 and T_3^8) were broken up several days after failure and pieces were cut from one end and from the center of each rod. The yield point of these twelve specimens was determined by the drop of the scale-beam, checked by means of dividers. The values thus found, as well as the corresponding values for unused rods of the Thacher type, are given in Table V.

TABLE V.—THACHER RODS.—ELASTIC LIMIT BEFORE AND AFTER TESTING IN CONCRETE BEAMS.

Values in Pounds per sq. in. Elastic Limit Determined by Drop of Beam.

Unused rods.	From 8-ft. beam.		From 5-ft. beam.	
	End.	Center.	End.	Center.
32,030	38,650	40,200	41,710	40,000†
36,450	40,200	41,130	42,930*	44,000†
34,640	39,700	41,960	49,920*	46,170*
Average	Average	Average	Average	Average
34,370	39,520	41,100	44,850	43,390

All others broke at connection between round and flat section.

It is seen that the average value of the elastic limit for these three unused rods is somewhat higher than the average of the two rods in Table IV. The average elastic limit of the five rods is 33,380 pounds. This average, as well as the maximum value, is less than the values found from the rods which had been molded in the beams.

Compression Tests.—The compression tests on the concrete for determining the modulus of elasticity were made on four 6 x 6-inch prisms, 24 inches long, 30 days old. Collars were attached to the prisms by means of pointed set-screws making contact at

* Broke in round section.
† Broke in flat section.

the center of the four sides. The gauge-length, center to center of set-screws in the upper and lower collars, was 18.5 inches. An Olsen compressometer, with micrometer reading directly to 0.0001 inch, was used for the measurements. The fingers of this instrument were put in contact with vertical extension rods of suitable lengths, attached to upper and lower collars at diagonally opposite corners. By electric contact in conjunction with a telephone receiver the apparatus was sensitive to one-half of one division, or 0.00005 inch.

The stress-strain diagrams for these prisms are plotted in Fig. 4. Beginning at the left, it will be seen from these diagrams that the modulus of elasticity was sensibly constant for the first three specimens up to a unit stress of about 500 pounds. Its value, in round numbers, for tests Nos. 1 and 2, up to this limit, was 2,000,000, and for test No. 3, 2,300,000. The diagram for No. 4 was less uniform. The value of the modulus of elasticity based on the

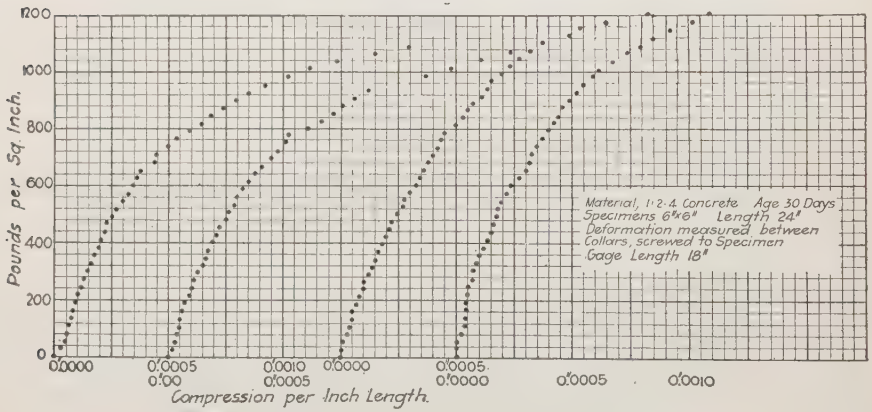


FIG. 4.—COMPRESSION TESTS OF PLAIN CONCRETE.

average up to 600 pounds per square inch was, in round numbers, 2,700,000. The ultimate compressive strength of these prisms was 42,000, 41,500, 46,000 and 47,500 pounds per sq. in. respectively.

Compression tests were also made on nine 6-inch cubes, molded from nine different batches of concrete used in making the beams. The resulting values, which were somewhat erratic, are shown in Table VI. Ten 6-inch cubes were also molded from a

single batch of concrete of the same composition used throughout these tests. The results for this series, which were much more uniform, also appear in Table VI.

The surfaces of these cubes were trowel-finished with the greatest care, and the loads were applied through flat metal bearings. The pressure was brought upon the upper plate through a spherical bearing block.

TABLE VI.—COMPRESSION TESTS ON SIX-INCH CUBES. ULTIMATE TOTAL LOADS IN POUNDS, AT THIRTY DAYS, IN AIR.

Cubes from different mixtures.	Cubes from single mixtures.
78,800	57,000
49,200	54,000
49,100	55,400
52,500	59,000
53,300	60,200
57,900	61,000
90,100	58,000
49,200	54,000
74,200	61,200
.....	50,000
Average	Average
61,600	57,000
1,710*	1,580*

It is to be observed that the same percentage of water (16 per cent of weight of sand and cement) was used for these prisms and cubes as for the beams. Two 6-inch cubes mixed with 10 per cent of water instead of 16 per cent, and thoroughly rammed, the one placed in water, the other in air for 30 days, developed a compressive strength of over 100,000 pounds, the capacity of the testing machine used.

Tension Tests.—The specimens for tensile tests were made of eye-bar form. The cross-section was 4 x 4 inches, the width of the heads 6 inches, the distance from center of $1\frac{1}{4}$-inch pin-hole to back of head was $2\frac{1}{2}$ inches. The gauge-length between centers of set-screws through upper and lower collars was $9\frac{1}{2}$ inches. The eye-bar heads were made of a rich mortar, reinforced with expanded metal curved half-way around the heads, midway between the pin-hole and the outer periphery. Five specimens were made of plain concrete, and four specimens were reinforced with single central rods of the four types used. In two specimens the heads

* Average ultimate strength, lbs. per sq. in.

were reinforced by means of pairs of expanded metal pieces parallel with the plane of the outer flat surfaces of the eye-bars. The pins were swiveled in double stirrups held in the grips of the machine. Micrometer readings were taken on opposite sides to 0.0001 inch.

In most cases the specimens broke in the body. The readings of the two micrometers were, however, so widely divergent and so erratic and the ultimate strength so low, that it was evident that, through slipping of the grips, and through want of provision for angular adjustment in the plane normal to the face of the bars, failure was brought about through bending. The results are considered valueless, and are not given. It was apparent, however,

TABLE VII.—PULLING-OUT TESTS.

Kind of rod.	Total load.	Load per lin. in of rod.	Remarks.
Johnson	13,660	1,138	Elastic limit passed. Concrete cracked.
	12,830	1,069	Elastic limit passed. Concrete cracked.
	9,980	832	Concrete cracked.
Plain	6,280	524	Rod pulled out.
	6,190	516	Rod pulled out.
	5,650	471	Rod pulled out.
Thacher	10,420	868	Rod broke.
	8,890	741	Concrete cracked.
	9,970	831	Rod broke.
Ransome	22,690	1,891	Concrete cracked.
	16,680	1,390	Concrete cracked.
	19,290	1,608	Rod pulled out.

that the elastic deformation of the bars provided with central reinforcement was considerably lower than that of the plain-concrete bars.

Adhesion or Pulling-Out Tests.—The tests for adhesion were made by imbedding the rods centrally in 6 x 6-inch concrete prisms, 12 inches long. The rods were imbedded for the entire length of the prisms. The specimens were molded with the rods lying horizontally as in the case of the beams. These tests were also made at the age of 30 days and the results are given in Table VII. The rod was passed through the movable cross-head of the machine and gripped in the upper fixed cross-head. The surface in contact

with the lower face of the movable cross-head was bedded in plaster-of-paris after the rod had been secured in the grips. The plaster was allowed to harden under an initial load of 1,000 pounds. In all cases where the concrete split the contact between the rods and the concrete proved to have been very good. It will be seen that in most cases failure occurred by the breaking of the rods or the cracking of the concrete, thus giving no definite indications of the value of the adhesion, or rather the strength of the bond.

Computations.—The computed unit stresses for the steel and concrete are given in Table VIII. These values are based on the mean loads at which visible hair-line cracks developed. For all

TABLE VIII.—UNIT STRESSES IN CONCRETE AND STEEL, IN LBS. PER SQ. IN., COMPUTED FROM MEAN LOADS AT WHICH VISIBLE HAIR-LINE CRACKS DEVELOPED.

Beams.	Mean Load at Hair-Line Crack, Lbs.	Neutral Axis, Distance Below Top of Beam.		Unit Stresses, Lbs. per Sq. In.			
				By Method A.		By Method B.	
		By Method A.	By Method B.	Steel.	Concrete.	Steel.	Concrete.
J^5	9,400	3.46	3.12	44,600	1,740	46,800	1,250
R^6	8,700	3.87	3.52	30,100	1,480	31,600	1,080
T^5	6,500	3.56	3.24	28,500	1,180	29,800	850
P^8	5,750	3.85	3.50	32,100	1,560	33,900	1,140
J^8	5,250	3.46	3.12	39,800	1,550	41,800	1,120
R^8	5,750	3.87	3.52	31,800	1,560	33,500	1,140
T^8	5,500	3.56	3.24	38,500	1,590	40,400	1,150

practical purposes failure may be regarded as having ensued at this stage of loading. The tensile resistance of the concrete is neglected. Although, doubtless, some residual tensile resistance remains in the concrete below the neutral plane when the hair-line cracks first appear, its amount is uncertain, and the neglect of this element involves a comparatively small error on the side of safety.

The stresses were computed by two well-known methods, both based on the theory of conservation of plane sections after flexure: *A*, on the assumption that the intensity of fiber stress varies directly with the distance from the neutral axis; *B*, on the

assumption that the intensity of fiber stress varies as the abscissas of a parabola whose axis is coincident with the extreme upper fibers. It may reasonably be held that the latter assumption accords more nearly with actual conditions, especially as failure is approached. The labor of computation is practically the same for both methods. The resulting values for the steel are almost identical by both methods; but the values of the extreme compressive fiber stresses in the concrete are about 27 per cent. lower by Method B. Since the final loads at complete failure of the individual beams are in almost all cases considerably higher than the average loads used in these computations, the stresses in the concrete, as computed by Method A, are doubtless considerably higher than those actually developed.

In the application of Method A, the mean value of the moduli of elasticity of the concrete in compression for unit stresses between the limits of 0 and 1000 pounds was used (see Fig. 4). This gave the ratio 25 between the moduli of elasticity of the steel and concrete.

Method B implies the assumption of a variable value for the modulus of elasticity of the concrete. The assumed value for the extreme fibers was based on the mean value from the direct compression tests for unit stresses between the limits 800 and 1000 pounds. The corresponding ratio between the moduli of elasticity of the steel and concrete is 44.

The number of tests on the different types of steel rods was not considered sufficient to warrant differences in the assumption of the modulus. Moreover, considerable variations in the assumed ratio of the moduli produce relatively small differences in the computed unit stresses. It is to be noted that the values of the unit stresses in the steel are usually far below the elastic limit. Only in the case of the T^8 beams is the elastic limit exceeded.

DISCUSSION.

T. L. CONDRON (by letter).—In connection with the papers presented at this meeting by Professors Talbot, Turneaure and Marburg, on the tests of reinforced concrete, the writer begs to report the results of a series of bending tests on steel concrete beams, at the Rose Polytechnic Institute, during the past winter, at which he assisted. These tests were made under the direction of Professor Malvard A. Howe, and described in a paper by him before the Western Society of Engineers, April 6, 1904, from which paper the following is abstracted: Mr. Condron.

"In order that the concrete and steel should represent products likely to obtain in practice, Atlas cement, bank sand, crushed rock and corrugated steel bars were purchased in the open market. The mixing was done by a local contractor of experience, with his own gang of men and in the manner he ordinarily employed.

"The quality of the materials was in general good. The cement was satisfactory in every way. The sand, while containing some 'dirt' in the form of yellow clay, was a fair representation of bank sand used in Terre Haute. The crushed limestone was in two parts, one coarse and the other fine, the two mixed forming the run of the crusher. The coarse stone would pass a screen of one and one-half inch mesh and would stop at one of one-half inch mesh; and the fine stone would all pass a screen of one-half inch mesh. The corrugated steel bars, when tested, showed an elastic limit of about 60,000 pounds, and an ultimate strength of about 100,000 pounds. The areas of the bars were, in general, as advertised with the exception of the $\frac{3}{4}$-inch bars, which were found to be about 20 per cent under size.

"The proportion of cement, sand and stone was practically one of cement to seven parts of sand and stone.

"The mixing was done on a concrete floor. The dry materials were placed in layers in the following order: stone, sand and cement. The mass was then turned twice dry and then twice wet, the water being introduced from a hose. The mixture was then shoveled into barrows and wheeled to the molds and dumped over the sides. Four to six inch layers were deposited the full length of the molds and tamped with iron tamping bars. The first two batches were moderately dry and the others pretty wet and required but little tamping.

"Very rigid knock-down moulds were used and no special means

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employed to obtain a smooth surface on the concrete, other than that given by mill-finished lumber. The molds were not wet before being filled and were not removed until the beam was to be tested. The beams were seasoned in basement rooms of a temperature of about 65° F.

"Table I shows the general dimensions of the beam and the arrangement of the steel bars. Although the beams were widely different in the dimensions of length and depth, yet all were designed on the same basis, the same percentage of steel being intended for each beam.

"In testing a beam the ends were supported in stirrups, free to swing on knife edges at about the center line of the beam. Two equal, concentrated loads were applied, symmetrically about the center of the

TABLE I.

MAKE-UP AND DIMENSIONS OF BEAMS.

Beam.	Made 1903.	Concrete Batch.	Number and Size of Steel Bars.	Nominal Areas.	Actual Net Areas of Steel.	Dist. Ctr. Steel below top of Beam *d*	Total Depth of Beam.	Br'dth of Beam.	Length of Beam Over All.
			IN.	SQ. IN.	SQ. IN.	IN.	IN.	IN.	FT. IN.
1	Oct. 13	1	2–½	0.36	0.36	4¼	5	12	12 0
2	Oct. 13	1	3–½	0.54	0.54	6¼	7	12	14 0
3	Oct. 13	2–3	4–½	0.72	0.72	8½	9½	12	17 0
4	Oct. 14	9	6–½	1.08	1.08	12¾	14	12	17 0
5	Oct. 14	5	2–¾	0.74	0.60	8¾	10	12	14 0
6*a*	Oct. 14	6	3–¾	1.11	0.90	13	14½	12	17 0
6*b*	Oct. 14	6	3–¾	1.11	0.90	13	14½	12	17 0
6*c*	Oct. 14	8	3–¾	1.11	0.90	13	14½	12	17 0
6*d*	Oct. 14	6–7	3–¾	1.11	0.90	13	14½	12	17 0
6*e*	Oct. 15	12	3–¾	1.11	0.90	13	14½	12	17 0
7*a*	Oct. 13	3–4	4–¾	1.48	1.20	17¼	19	12	19 6
7*b*	Oct. 13	4	4–¾	1.48	1.20	17¼	19	12	19 6
7*c*	Oct. 14	9–10–11	4–¾	1.48	1.20	17¼	19	12	19 6
7*d*	Oct. 14	7	4–¾	1.48	1.20	17¼	19	12	19 6
7*e*	Oct. 14	9	4–¾	1.48	1.20	17¼	19	12	19 6
8	Oct. 13	2	2–⅞	1.10	1.06	12¾	14	12	17 0
9	Oct. 13	5	3–⅞	1.65	1.59	19¼	21	12	19 6
11	Oct. 14	8	2–1	1.40	1.40	16¼	18	12	19 6

beam, through knife edges in rolling seats, thereby producing a constant bending moment between the points of application of the loads (excepting the variable moment produced by the weight of the beam). The rolling seats for the knife edges were supported by ¾ x 4-inch steel plates, bedded in plaster of paris on top of the beam.

"Table II gives the result of the tests in terms of the loads, bending moments and mode of failure. Table III was computed by Johnson's Formula using the value of y_1 obtained from the experiments. This value was, in most cases, found graphically. For four beams, however, it was computed and the resulting values plotted. These lines showed that at the commencement of the loading the neutral axis was below the

center of the beam. As the load increased in magnitude, the axis moved upward very rapidly until cracks commenced to appear on the bottom of the beam; then the axis remained approximately in the same position as long as the concrete did not show signs of failure in compression, as indicated by the drop of the scale beam. At or near the end of the experiment the axis, sometimes, not always, dropped suddenly. Mr. Condron.

TABLE II.

MAXIMUM LOADS AND MOMENTS.

Beam.	Age in Days.	Span c-c End Support.	Dist. between Loading Points.	Total Weight of Beam.	Total Max. Load.	Load when Comp. Failure was marked. Load Falling off from Max.	Max. Moment 1000s of in Lbs.	Theoretical Moment Johnson's Formula.	See Foot Note
		FT. IN.	FT. IN.	LBS.	LBS.	LBS.	LBS.	LBS.	
1	74	10 0	3 4	825	4,200	3,400	94.3	80.6	
2	76	12 0	4 0	1,150	8,100	5,100	212.2	174.2	
3	72	15 0	5 0	2,000	12,100	.....	402.7	322.2	
4	73	15 0	0	2,860	19,400	.....	929.8	725.0	[1]
5	71	12 0	4 0	1,700	11,900	.....	311.9	283.0	
6*a*	71	15 0	5 0	2,935	18,300	.....	607.2	625.0	
6*b*	69	15 0	5 0	2,950	19,325	16,500	638.3	625.0	
6*c*	115	15 0	5 0	2,450	20,400	19,100	666.3	625.0	
6*d*	29	15 0	3 0	2,960	15,500	.....	616.8	625.0	[2]
6*e*	29	15 0	3 0	3,125	17,000	.....	692.0	625.0	[3]
7*a*	78	18 0	6 0	4,450	30,000	28,500	1,189.4	1,121.0	
7*b*	78	18 0	6 0	4,325	29,000	23,600	1,152.0	1,121.0	
7*c*	70	17 9	6 0	3,800	30,100	.....	1,142.9	1,121.0	
7*d*	68	18 0	8 0	4,450	29,900	.....	1,006.4	1,121.0	[4]
7*e*	77	17 6	3 0	4,200	22,800	.....	1,090.7	1,121.0	[5]
8	77	15 0	5 0	2,900	23,300	22,300	756.5	725.0	
9	77	18 0	6 0	4,850	34,800	.....	1,373.7	1,652.6	[6]
11	75	18 0	6 0	4,225	29,000	25,700	1,149.3	1,177.8	

[1] 14,000 applied 6 feet 6 inches. Removed and loaded in center. Failed at load.

[2] Failed by Comp. near center.

[3] Failure same as 6*d*. Made of gravel from pit.

[4] Several repetitions of load. Failed by shearing.

[5] Repeated loads. Failed by shearing.

[6] Failed by shearing.

"The values of y_1 are probably in error, but not enough to be of any practical importance. The travel of the neutral axis is correctly obtained by the methods employed (assuming that a plane section remains plane after its distortion of the fibers), but its exact location in reference to the center of the beam is not known, as the experiments were commenced under an initial load including the weight of the beam.

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"Table IV was computed, using the same values of y_1 as employed in Table III, under the assumption that the concrete resisted no tension, and that in compression the distortion of the concrete was proportional to the stress producing it."

TABLE III.

FIBER STRESSES ACCORDING TO JOHNSON'S FORMULA AND EXPERIMENTAL y_1.

Beam.	Center of Steel Below Top of Beam d	Neutral Axis Below Top of Beam. y_1	Max. Stress in Concrete in Comp. Lbs. per Sq. Inch.	Concrete in Tension. Lbs. per Sq. Inch	Steel in Tension. Lbs. per Sq. Inch.	Batch in Top of Beam.	See Foot Note
	IN.						
1	$4\frac{1}{4}$	$0.45d$	1,700	170	66,000	1	
2	$6\frac{1}{4}$	$0.45d$	1,900	190	66,000	1	[1]
3	$8\frac{1}{2}$	$0.38d$	2,300	230	64,000	3	[2]
4	$12\frac{3}{4}$	$0.34d$	2,500	250	64,800	9	[3]
5	$8\frac{3}{4}$	$0.42d$	1,500	150	60,500	5	
6a	13	$0.37d$	1,500	150	51,000	6	
6b	13	$0.37d$	1,500	150	54,000	6	[4]
6c	13	$0.42d$	1,400	140	58,300	8	
6d	13	.....	.....	.....	.....	7	[5]
6e	13	.....	.....	.....	.....	12	[5]
7a	$17\frac{1}{4}$	$0.39d$	1,600	160	57,000	4	[6]
7b	$17\frac{1}{4}$	$0.53d$	1,600	160	53,500	4	[7]
7c	$17\frac{1}{4}$	$0.36d$	1,600	160	53,500	11	
7d	$17\frac{1}{4}$	$0.35d$	1,400	140	47,600	7	[8]
7e	$17\frac{1}{4}$	$0.35d$	1,600	160	52,200	9	[8]
8	$12\frac{3}{4}$	$0.36d$	2,000	200	54,000	2	
9	$19\frac{1}{4}$	$0.40d$	1,400	140	45,000	5	[9]
11	$16\frac{1}{4}$	$0.39d$	1,700	170	50,500	8	[10]

The writer has made a complete set of diagrams of the deflections and extensometer readings for these eighteen beams. The deflection curves are practically straight lines from a point approximately one-fourth of the maximum load, until the maximum load is reached, when the beam deflects rapidly under a constant load.

[1] Reset upper arc at 6,000 pounds.
[2] Cord of upper arc touched at 7,000 pounds.
[3] Center load, hence axis may not be correctly located.
[4] Repeated loading.
[5] No records for y_1.
[6] Cord of upper arc touched at 25,000 pounds.
[7] Cord of lower arc touched at 6,000 pounds.
[8] Repeated loads and failed in shear.
[9] Failed in shear.
[10] Upper cord touched at 16,000 pounds.

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In most of the beams tested, fine hair-cracks began to appear in the lower or tension side of the beams at about one-third of the maximum load, and the concrete crushed under the maximum load in 15 of the 18 beams. These cracks did not open up to any serious extent until nearly the maximum load was reached, when the stretching of the steel beyond its elastic limit permitted them to increase rapidly.

TABLE IV.

FIBER STRESSES ACCORDING TO COMMON THEORY AND EXPERIMENTAL y_1.

Beam.	Max. Comp. in Concrete. Lbs. per Sq. In.	Tension in Concrete.	Tension in Steel. Lbs. per Sq. In.	Remarks.
1	2,120	Concrete assumed to take no tension.	76,500	See Table III.
2	2,380		76,500	
3	2,870		74,300	
4	3,100		75,500	
5	1,900		56,000	
6a	1,900		59,300	
6b	1,900		62,500	
6c	1,750		67,700	
6d	.....		.....	
6e	.....		.....	
7a	2,000		66,400	
7b	2,000		62,000	
7c	2,000		62,000	
7d	1,800		55,500	
7e	2,000		60,000	
8	2,500		64,200	
9	1,750		52,200	
11	2,100		58,100	

The deflection and extensometer curves seem not to be affected by the cracking of the concrete on the tension side after the load has passed beyond the region of Professor Hatt's point "A." Up to this point the tensile strength of the concrete has been in play, but beyond this point the steel seems to take up all of the tension stress.

ADDENDUM, OCTOBER 24, 1904.

Mr. Condron.

Since the June meeting of the Society the writer has made a comparative study of the results obtained by Professors Hatt, Talbot, Marburg, Turneaure, and Howe, in the testing of reinforced concrete beams. In this connection he presents herewith three diagrams.

In order to study the results of all of the tests referred to, the ultimate bending moment developed in each test has been computed from the weight of the beam and the maximum applied load. This moment (M) has been divided by the breadth (b), times the square of the depth (d^2) of the beam. The depth considered has in every instance been taken as the distance from the compression face to the plane of the reinforcing metal. Also the percentage of reinforcing (P) has been calculated, basing this percentage upon the ratio of the area of steel bars, (A) to the area of the beam (bd), above the plane of the reinforcing bars, or $P = 100\ A \div bd$.

The diagrams here presented, Figs. 1, 2 and 3, are the graphical representations of the results of all of these tests, reduced to the above basis. The vertical ordinates represent values of $\frac{M}{bd^2}$ and the horizontal ordinates values of P. Figure 1 shows the results of the tests by Professor Talbot, at the University of Illinois. The two lines on this diagram passing through the tests of beams reinforced with (1) plain bars having an elastic limit of approximately 33,000 pounds per square inch and (2) of beams reinforced with bars of approximately 55,000 pounds elastic limit (Johnson bars) have been repeated on the other two diagrams as reference lines. As will be observed, these lines are straight for the greater part of their lengths. The equation of these lines is $\frac{M}{bd^2} = mP + n$. For plain bars $m = 275$; and for Johnson bars $m = 450$; while $n = 55$, is common to all lines being the value of $\frac{M}{bd^2}$ when $P = O$, or since there is no reinforcing, in this case, d becomes h, the full depth of the beam. The results of 28 tests of concrete beams reinforced with plain steel bars, having an elastic limit of approximately 33,000 pounds, are shown on the diagram Fig. 2;

and the results of 40 tests of concrete beams reinforced with cor- Mr. Condron.
rugated bars of approximately 55,000 pounds and 15 tests of plain steel bars of approximately 75,000 pounds elastic limit, are

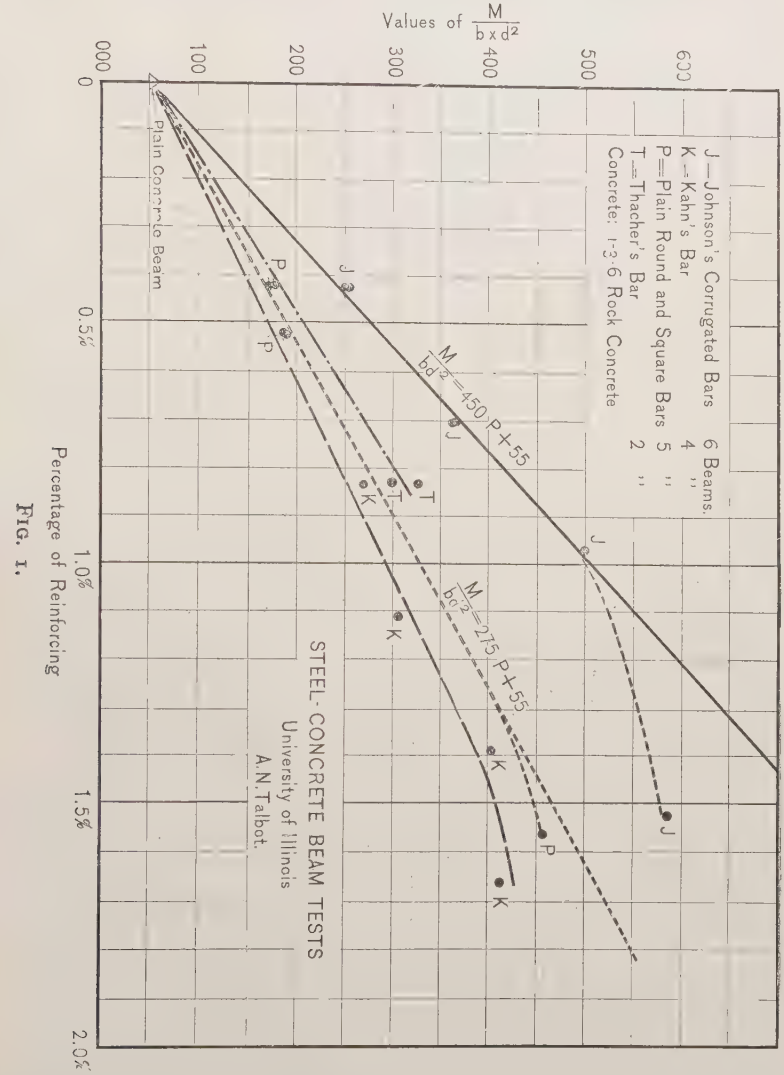

FIG. 1.

shown on the diagram, Fig. 3. From these three diagrams, which represent 89 beams, it will be seen that beams may be proportioned

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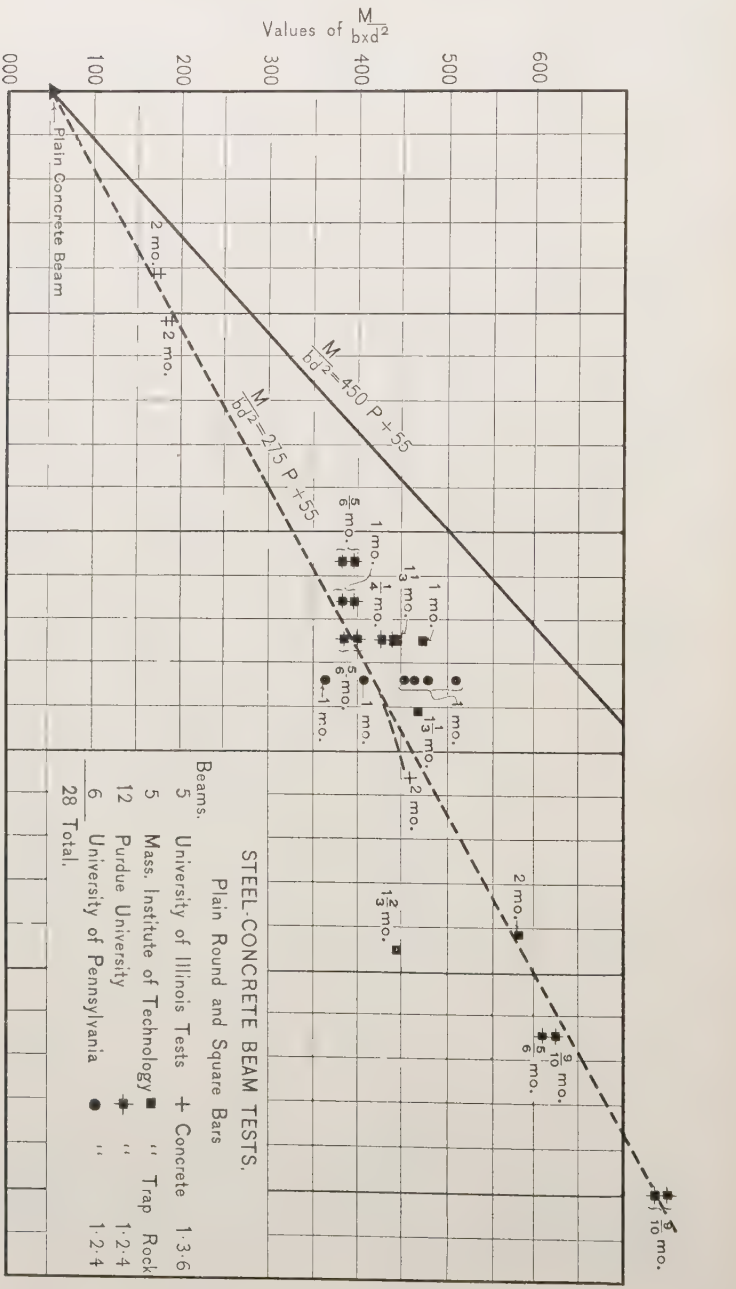

FIG. 2.

by straight line empirical formulas quite as correctly as by more involved theoretical formulas. Mr. Condron.

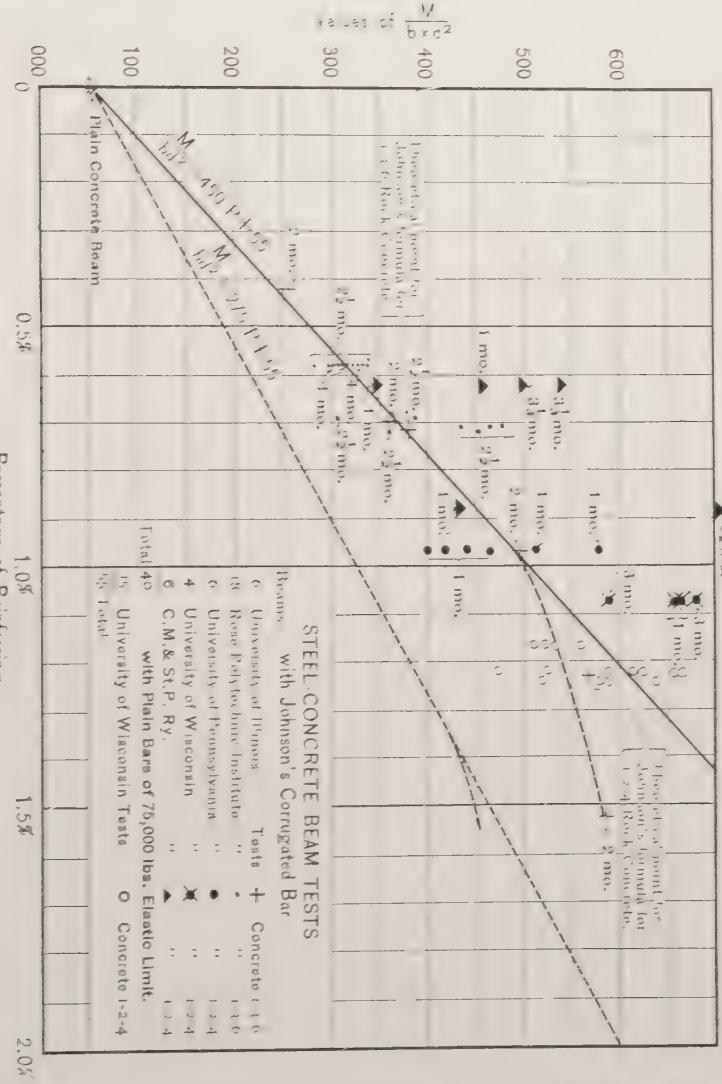
Values of $\frac{M}{b \times d^2}$
0
100
200
300
400
500
600
0.5%
1.0%
1.5%
2.0%
Percentage of Reinforcing
Plain Concrete Beam
$\frac{M}{bd^2} = 450\ p\ (1 - 0.5\ p)$
$\frac{M}{bd^2} = 900\ p\ (1 - 0.5\ p)$
Theoretical parabola for Johnson's formula for 1-2-4 Rock Concrete.
STEEL-CONCRETE BEAM TESTS
Beams with Johnson's Corrugated Bar
6 University of Illinois Tests + Concrete 1-2-4
18 Rensselaer Polytechnic Institute " • " 1-2-4
6 University of Pennsylvania " ● " 1-2-4
4 University of Wisconsin " ✖ " 1-2-4
6 C.M. & St.P. Ry. " ▲ " 1-2-4
Total 40 with Plain Bars of 75,000 lbs. Elastic Limit.
15 University of Wisconsin Tests ○ Concrete 1-2-4
55 Total

FIG. 3.

It seems impossible to get a simple formula that will fit all possible conditions of concrete and kinds of reinforcing bars, but

Mr Condron. it is very evident that all formulas based upon the ultimate strength of the steel being reached at the time of the failure of the reinforced concrete beam are in error. It is moreover dangerous to use steel of 60,000 pounds per square inch ultimate tensile stress and say, that when this steel is stressed to 15,000 or 16,000 pounds per square inch, there is still a factor of safety of four in the structure.

If the tests that have been made at the several laboratories of our leading Universities during the past year teach us anything, it is that the ultimate strength of reinforced concrete beams is reached when the reinforcing metal is stressed to its elastic limit, or yield point.

With reference to the cracking of the concrete on the tension side, Prof. Turneaure has shown that these cracks appear very early in the test, but that they remain microscopical until the steel is stressed to about 12,000 to 15,000 pounds per square inch. Above this point the cracks are liable to open wide enough to increase the porosity of the concrete. Therefore, we should restrict our working stresses to such a point as will not cause the reinforcing bars to be stressed beyond about 12,000 pounds per square inch. Therefore, steel of 50,000 pounds elastic limit, or 100,000 pounds ultimate strength, gives a factor of safety of four between the safe working load and the ultimate carrying capacity of the beam. If ordinary steel of 30,000 pounds elastic limit, or 60,000 pounds ultimate strength, is used, the factor of safety is but two and a half with a working stress of 12,000 pounds. Several writers have proposed working stresses of 16,000 pounds per square inch in the steel when steel of 60,000 pounds ultimate strength is used and have claimed that there will then be a factor of safety of four, but all these tests disprove this method of calculation and show that the factor of safety in such cases is less than two. Is it any surprise that failures occur under such conditions?

Until the writer finds a better way of calculating the strength of reinforced concrete beams he will content himself with following the equations of the two lines shown on the diagrams he presents here, Figs. 1, 2, and 3. That is, for plain steel bars of approximately 33,000 pounds per square inch elastic limit he will use, $M = 275\ P + 50$; P not to exceed 1.5 per cent. For corrugated or similar bars of approximately 55,000 pounds per square inch elastic limit, he will use $M = 450\ P + 50$; P not to exceed $1\frac{1}{4}$ per

cent., M being the *ultimate* moment of resistance in inch pounds. To obtain this moment, add to four times the dead load moment four to eight times the live load moment depending upon the character of loading considered. In every case the concrete to be of first-class quality and at least as rich as 1:3:6 for broken stone and 1:5 for clean sand and gravel. Mr. Condron.

It is evident, from Prof. Turneaure's tests with high elastic plain steel bars (75,000 pounds elastic limit), that when steel of such strength is used, plain bars will not develop as much strength for the same percentage of reinforcing as though the bars were deformed. Of course, under anything but static loads the difference becomes even greater.

SANFORD E. THOMPSON (by letter).—The aim of such important series of tests of reinforced concrete beams as we had presented by Professors Marburg, Talbot and Turneaure is toward the establishment of laws and the confirmation of theories which will enable us to design beams of reinforced concrete with minimum quantities of steel and of cement and yet with positive assurance of safety. Mr. Thompson.

The most important point which has been clearly, and it would seem positively, established by these tests, is the fact that the pull in the tension portion of the beam is actually transferred to the steel at an early period in the test, usually before the working strength of the beam is reached. This is indicated not only by Prof. Turneaure's observation of the water-marks, but as well, as suggested by Prof. Talbot, by the marked change in character of the curves in the various diagrams, when the load is transferred to the steel. The practice which has already been generally adopted of neglecting all strength of the concrete in pull may therefore be considered correct, not only from the point of view of safety, but also from a rational standpoint.

Another conclusion—an extremely important one in the opinion of the writer—that may be drawn from the tests, especially from those of Prof. Talbot, which embrace the widest range in reinforcement, is that computations made according to the usual beam theories (based on the elasticity and the stresses in the concrete and the steel) produce values for the location of the neutral

Mr. Thompson.

axis, and also for the ultimate moment of resistance, which are so near the experimental results that the theoretical formulas may be safely employed, if proper unit stresses and moduli are used.

The proof of the lack of tensile resistance in the concrete under normal loading enables us to consider the resistance of the beam as a couple, whose forces are the pressure in the concrete and the pull in the steel, and whose arm is the distance between these forces. Therefore, the moment of resistance may be obtained by taking moments about both forces, and adopting the lower value.

The location of the center of pull in the steel is evidently at the center of gravity of the steel rod or rods. The location of the center of pressure in the concrete has not yet been clearly fixed because the various experiments in this country and abroad have been made with concretes of various and, in many cases, undefined proportions and consequently of different strength and elasticity. The location of the center of pressure of the concrete is based on the location of the neutral axis in the beam and the distribution of the pressure above the neutral axis, which, in turn, if the fundamental principles of theory are correct, depend upon the moduli of elasticity of the steel and the concrete.

In the table which follows are presented for comparison the actual location of the neutral axis as determined by Prof. Talbot's experiments, column (7); the values calculated by his empirical formula (p. 483), column (8); the values calculated by the theory of the straight-line distribution of pressure, column (9), and by the theory of the parabola distribution of pressure, column (10); also Prof. Talbot's estimated bending moments in columns (11), and the moments of resistance calculated by the straight-line and by the parabola theories in columns (12) and (13).

The measured depths of the neutral axis, column (7), are taken directly from Prof. Talbot's tabulation of the actual positions during the third stage of each beam, as given in his paper in the University of Illinois *Bulletin*, September, 1904.

The close agreement of the values by Prof. Talbot's formula, column (8), with the measured values, indicates the possibility of determining for such a formula, constants, each of which will apply to a certain class of concrete. The exact values of the constants are of course dependent upon the strength and elasticity of the concrete, and therefore the values given in the original

COMPARISON OF PROF. TALBOT'S RESULTS WITH THEORETICAL COMPUTATIONS.

Beam No.	Kind of Steel.	No. of Rods.	Size of Rods. in.	Ratio of Area of Steel to Beam above Steel.	Load Considered. lb.	Ratio of Depth of Neutral Axis to Depth of Steel. As Measured.	Calculated by Talbot's Formula.	Calculated by Straight-line Theory	Calculated by Parabola Theory.	Estimated Total Bending Moment.* in.-lb.	Moment of Resistance calculated by Straight-Line Formula. in.-lb.	Moment of Resistance calculated by Parabola Formula. in.-lb.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
21	Round	3	½	0.0041	8,000	0.34	0.33	0.33	0.29	261,000	226,890*b*	226,850*b*
19	Round	3	½	0.0041	9,200	0.36	0.33	0.33	0.29	294,600	226,890*b*	226,850*b*
16	Square.....	3	½	0.0052	9,900	0.37	0.35	0.36	0.32	313,200	284,700*b*	284,550*b*
17	Square.....	3	½	0.0052	9,500	0.37	0.35	0.36	0.32	302,000	284,700*b*	284,550*b*
27	Square.....	4	¾	0.0156	25,000	0.53	0.54	0.54	0.49	725,500	774,000*a*	793,200*b*
9	Ransome....	3	½	0.0052	18,000	0.34	0.35	0.36	0.32	540,000	474,500*c*	474,200*c*
15	Thacher	3	¾	0.0083	15,500	0.41	0.41	0.43	0.39	466,000	443,300*b*	442,300*b*
10	Thacher	3	¾	0.0083	14,500	0.43	0.41	0.43	0.39	438,000	443,000*b*	442,300*b*
22	Kahn	3	¾	0.0167	22,000	0.51	0.56	0.55	0.50	641,000	786,200*a*	843,000*b*
4	Kahn	5	½	0.0139	21,000	0.47	0.51	0.52	0.47	615,000	714,800*b*	711,800*b*
14	Kahn	4	½	0.0111	17,000	0.46	0.46	0.48	0.43	505,500	580,400*b*	578,600*b*
5	Kahn	3	½	0.0083	13,000	0.42	0.41	0.43	0.39	396,000	443,200*b*	442,300*b*
28	Johnson	6	¾	0.0152	31,000	0.53	0.53	0.53	0.48	893,500	768,700*a*	927,800*a*
13	Johnson	7	½	0.0097	27,500	0.45	0.43	0.46	0.41	800,500	681,400*a*	817,700*a*
20	Johnson	5	½	0.0069	20,000	0.44	0.39	0.41	0.36	593,500	615,600*a*	621,200*b*
2	Johnson	5	½	0.0069	19,000	0.39	0.39	0.41	0.36	565,500	615,600*a*	621,200*b*
7	Johnson	3	½	0.0042	13,000	0.33	0.33	0.33	0.30	401,000	384,400*c*	384,200*c*
3	Johnson	3	½	0.0042	12,000	0.31	0.33	0.33	0.30	373,000	384,400*c*	384,200*c*
					Average	0.418	0.411	0.422	0.378	506,906	507,388	533,711

NOTE.—Columns (1), (2), (3), (4), (6), (11), are taken from Prof. Talbot's Table.

* As calculated by Prof. Talbot, based on "Load Considered," column (6).

a Based on crushing strength of concrete, 2,030 lb. per square inch, because the moment thus obtained is lower than the moment based on yield point of steel.

b Based on yield point of mild steel as 36,000 lb. per square inch. *c* Based on yield point of high steel as 60,000 lb. per square inch.

Mr. Thompson. formula cannot be applied directly to concrete of a different character.

The theoretical calculation for the location of the neutral axis is much simplified by the elimination of tensile resistance in the concrete, since it appears from experiments that the location of the neutral axis after the pull has been transferred to the steel must lie either in the position calculated by the straight line distribution of pressure—which assumes that a plane section before bending is also plane after bending and that the modulus of elasticity is constant during working limits—or by the parabola theory —which assumes a clearly defined decrease in the modulus—or else between these two positions. The values in columns (9) and (10) therefore present extremes with the particular modulus of elasticity selected.

In calculating columns (8), (9), (10) and (13) of the table, the modulus of elasticity of concrete is taken at 1,500,000. Prof. Talbot's tests* of elasticity show this to be a fair average value for the concrete which he used, between pressures of 1,000 and 1,700 pounds per square inch, stresses which correspond to the pressure in the beam when the neutral axis is as measured. This modulus also gives, by the straight line theory, proportional values for the location of the neutral axis which are nearest to the measured locations. By the parabola theory a still lower modulus would have shown better results.

In calculating the values for the moments of resistance, the yield points of the steel are taken at average values for high and low steel respectively, so as to compare the tests with results which would be reached by theoretical calculations. Similarly, the ultimate crushing strength of the concrete is assumed as 2,030 pounds per square inch, which is the average strength found by Prof. Talbot in his tests upon 6-inch cubes.

It is noticeable that the neutral axis calculated by the straight line theory of pressure distribution, column (9), agrees almost exactly with the measured values in column (7). The ratios by the parabola theory are lower, that is, the location of the neutral axis in the beam is higher. It is also interesting to observe that the values in columns (9) and (10) are nearly but not quite proportional to each other.

* Journal Western Society of Engineers, Aug. 1904.

Mr. Thompson

The moments of resistance in column (12) agree as nearly as could be expected with the estimated bending moments in column (11). The moments calculated by the two theories, columns (12) and (13), agree almost exactly in the tests based on the pull in the steel. In tests (28) and (13), in which both columns are based upon an ultimate strength of concrete of 2,030 pounds per square inch, the parabola values are nearer to the actual bending moments than the straight line values, showing that for the latter a crushing strength of concrete higher than 2,030 could have been assumed. On the other hand, tests (27), (22), (20) and (2), which by the parabola theory have to be calculated from pull in the steel, because this gives the lower moment of resistance, are not in column (12) quite so near to the estimated bending moments as by the straight-line theory, which assumes the concrete to be the limiting material.

The important part which the quality of the concrete plays in reinforced beams has sometimes been overlooked in theoretical studies of the combination of concrete and steel. This is well illustrated by the fact that Prof. Talbot's beams, as stated above, require calculation with the use of a modulus of elasticity of not more than 1,500,000, corresponding to a ratio of 20, in order to bring the neutral axis as low in the beam as his measured depths. To obtain theoretical results with Prof. Hatt's beams* agreeing with actual tests, one must employ, as Prof. Hatt suggests, a modulus of about 4,000,000, corresponding to a ratio of 7.5. For Prof. Turneaure's tests presented in this volume, I find a modulus of 2,500,000, or a ratio of 12, to give locations of the neutral axis which fairly agree with his experiments. The reason for such variation presents an important field for experimental investigation.

The formulas† used in calculating the location of the neutral axis, columns (8) and (10), and the moments of resistance, columns (12) and (13), are as follows:

Let

p = ratio of area of steel to area of beam above the center of gravity of the steel.

C = unit pressure in outside fiber of concrete.

*Proceedings American Society for Testing Materials, 1902.

†The derivation of these formulas is presented in Taylor and Thompson's Treatise on Concrete, Plain and Reinforced, 1905

Mr. Thompson.

S = unit pull in steel.

$r = \frac{E_S}{E_C}$ = modulus of elasticity of steel divided by modulus of elasticity of concrete in compression.

d = distance from outside compressive surface to center of gravity of steel.

xd = distance from outside compressive surface to neutral axis in a beam having steel at depth, d, below the outside compressive surface.

x = ratio of depth of neutral axis to depth of steel, from outside compressive surface.

M_R = moment of resistance.

By the straight line theory the proportional depth of the neutral axis is

$$x = rp\left(\sqrt{1 + \frac{2}{rp}} - 1\right)$$

and the formula for the moment of resistance is

$$M_R = pSbd^2\left(1 - \frac{x}{3}\right)$$

or

$$M_R = \frac{Cxbd^2}{2}\left(1 - \frac{x}{3}\right)$$

Similarly, by the parabola theory, the proportional depth of the neutral axis is

$$x = \tfrac{3}{4}rp\left(\sqrt{\frac{8}{3rp} + 1} - 1\right)$$

and the formula for the moment is

$$M_R = \tfrac{2}{3}Cxbd^2\left(1 - \frac{3x}{8}\right)$$

or

$$M_R = Spbd^2\left(1 - \frac{3x}{8}\right)$$

Mr. Talbot.

ARTHUR N. TALBOT (by letter).—Mr. Thompson in his discussion utilizes the method of determining the moment of resistance of the beam used by the writer in his paper, taking

the moment of the couple formed by the resultants of the tensile stresses and the eompressive stresses. This is clearly the best method for making calculations, especially if the tensile stresses are fairly definitely known and the compressive stress at the upper surface is less than the limiting value. For these conditions it is not of so much importance that the neutral axis be accurately determined, or that the exact distribution of the compressive stresses be known, for a slight variation in these will have a relatively small effect on the value of the resisting moment. However, if the compressive stress at the upper surface is desired, some further knowledge of the distribution of the compressive stresses is needed. Mr. Talbot.

It is to be expected, then, that the formulas based upon the straight-line deformation relation, or other relations somewhat similar, will give results for the position of the neutral axis and for the resisting moment within limiting values of tensile stresses quite close to observed results, particularly if the coefficient of elasticity is chosen for the size of beam and for the concrete used, as it would be if a value were chosen to fit the results of the beams. It is not so apparent that the compressive stress at the upper surface or the limiting resisting moment for the concrete may be determined by such a formula. The inaccuracy of this method is shown by some of the results noted by Mr. Thompson as lacking in compressive strength, for the deformations given in the diagrams for the beams indicate that the concrete is not near failure. Calculations of compression based on straight-line stress-deformation relation seem to be not fully satisfactory.

Attention may be called to the fact that in the derivation and use of formulas the parabolic stress-deformation relation is sometimes loosely and even inconsistently used. For example, to call the compressive stress distribution in a beam a parabola and then call the modulus of elasticity a constant is illogical. Something of this kind must have been done in the calculation of column (10) of Mr. Thompson's table, for the parabolic relation should give positions of the neutral axis closely following the observed results, as is seen by the curved lines of the diagram for position of the neutral axis in the original paper of the writer. Similarly, values for the resisting moment in column (13) based

Mr. Talbot.

upon compressive strength must be untrustworthy, and values for C in the parabolic formula given by Mr. Thompson should not be used as a test of the accuracy of the parabolic stress-deformation relation. For a fuller discussion of such matters, reference may be made to a paper by the writer in Journal of Western Society of Engineers for August, 1904.

It must be conceded that the distribution of the compressive stresses in a reinforced concrete beam and the intensity of the stress at the upper surface are not accurately known. It is hoped that investigations may be directed along this line, for it is important to be able to determine the stress in the remotest fibre for different concretes in order to judge of the compressive strength of the beam. It would seem that the strength on the compression side is greater than it has been considered to be, or that it is not determinable by direct comparison with the strength of concrete cubes. While our most pressing need is the determination of the limiting amount of steel for different concretes, yet the investigation of internal compressive stresses should not be overlooked.

MECHANICAL DEFECTS IN SIEVES USED FOR TESTING CEMENT.

By E. W. Lazell.

In order to carry out the methods for uniform tests of cement it is necessary to have the apparatus used, and the methods employed, uniform. It was with the idea of standardizing the apparatus that this investigation was undertaken, as it is self-evident that to be able to obtain concordant results the apparatus used by different testors must be standard.

The determination of the fineness of cement is one of the most important investigations undertaken in the testing of cement, for this shows the care the manufacturer has taken in finishing his product.

It is well established that the very fine flour which passes the finest sieves is the part of the cement which gives to it its binding property. This flour, owing to its fine subdivision, is the part acted upon by water, while the coarser particles are slowly if ever attacked. Recent microscopical investigations of both neat and sand briquettes show that only the extremely fine particles of cement are attacked by water, the coarser particles retaining all the properties of the original cement clinker. Also, the manufacturer is interested in the fineness to which the raw materials are ground, as on the fine grinding and intimate mixing of the ingredients depends their subsequent union in the kiln to clinker. The finer the raw materials are ground and the resulting more intimate mixture of the argillaceous and calcareous parts, thus increasing the surface of contact between them, the greater the ease with which the ingredients unite in the kiln. Coarse particles are slowly acted upon at the temperature of the kiln, and then only on the surface; thus the output of the kiln is materially reduced by the coarseness of the material which is fed to it, it being a well-known chemical fact that the more intimately the materials are mixed, and the finer these materials are, the

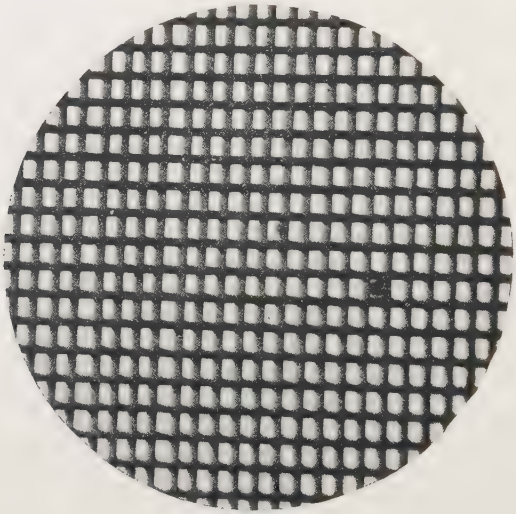

FIG. 1.—No. 50 Sieve. Enlargement 5.8 diameters.
Mesh by count 2160 per square inch.

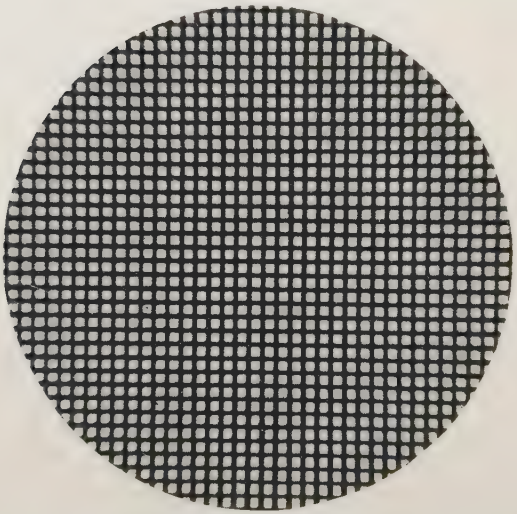

FIG. 2.—No. 100 Sieve. Enlargement 7. diameters
Mesh by count 9800 per square inch,

greater the ease of the progression of the reaction. Fine grinding of the raw materials would thus result in a greater output and a decreased coal consumption.

By this introduction the writer has endeavored to show the necessity of obtaining an accurate method for determining the fineness to which both the raw materials and the cement have been ground, and one giving results that are uniform and agree among themselves.

The usual method at present for determining the fineness is by means of sieves made of fine wire cloth. Granting that the sieves are uniform and that the manipulation is carefully done, then the determination of fineness made in different laboratories should check within 2 per cent or closer. Any one familiar with cement testing knows that agreements as close as these are rare, and that cement which has shown a certain fineness by the mill tests often fails when samples are taken from the same cement at the place it is to be used. This point is well illustrated by the results obtained on the samples of cement sent out to be tested by your Committee last year. On the same sample different laboratories obtained results which varied as much as 10 per cent for both the No. 100 and No. 200 sieves, laboratories reporting for the same sample 94 to 84 per cent to pass the No. 100 sieve.

Some time since a number of samples of cement were tested for fineness, and the results obtained varied from results found by others upon the same samples. The cement was retested a number of times, different sieves being used each time, giving results which varied greatly. This led to the investigation of the sieves themselves. A linen tester was procured and the meshes were counted. This work was very tedious, especially in the finer sieves, and the results did not show any individual variation in the mesh, also no record was preserved. To facilitate the ease of counting the meshes, and to procure records which could be kept and referred to at any time, it was decided to obtain enlarged photographs of the sieves in order that the meshes could be more readily counted and that any individual variation would be at once apparent. The photographs which you have in your hand are some of the results obtained. Some of these represent sieves that have been in use for some time, while others are photographs of new sieves, and some few are from samples of cloth from various sources. In most

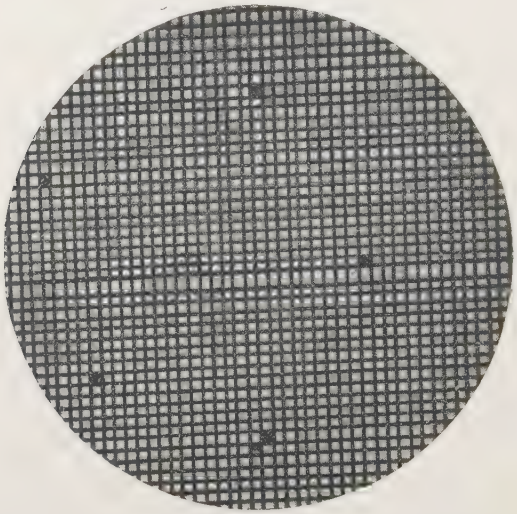

FIG. 3.—No. 100 Sieve. Enlargement 5.6 diameters.
Mesh by count 9408 per square inch.

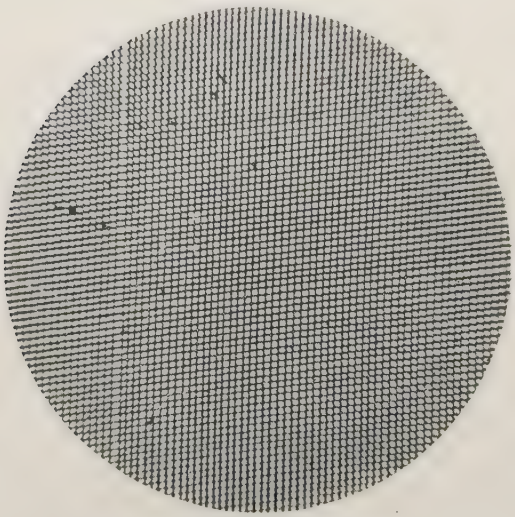

FIG. 4.—No. 200 Sieve. Enlargement 7. diameters.
Mesh by count 38,808 per square inch.

cases the samples of cloth closely approximate the correct number of meshes to the inch, so that the greater part of the variations in the sieves themselves is due to straining the cloth in the manufacture of the sieves.

The defects commonly met with in sieves are as follows:

First. Variations from the correct number of meshes to the linear inch. The writer has examined cloths said to contain 200 meshes per linear inch, and has found by actual count as low as 170. Shown in Fig. 1.

Second. Unequal size of the meshes in different parts of the same sieve, shown very clearly in Figs. 3 and 4.

Third. Variation in the gage of the wire in different cloths. Some years ago it was hard to obtain No. 200 sieves from different manufacturers the cloth of which was woven from wire having the same gage. In this line there has been a marked improvement in the past few years, the manufacturers approaching a closer standard.

Fourth. Unevenness in the mesh of the cloth due to straining or displacement brought about in the making of the sieve. Shown in Fig. 4.

The photographs show these very clearly. These wider meshes allow coarser particles to pass, and by this means vitiate the results. A common defect in sieves, also clearly shown, is the displacing of the wires so that they are no longer perpendicular to each other, the holes being no longer rectilinear. See Figs. 4 and 6. Such a sieve the writer considers unfit for use.

Fig. 2 shows a very perfect sieve, the meshes being 98 one way and 100 the other.

The report of the Committee of the American Society of Civil Engineers on Tests of Cements, recommends the limits of variations in sieves to be for the No. 100 sieve 96 to 100 meshes to the linear inch, and the No. 200 between 188 and 200 meshes to the linear inch.

By this method of testing the sieves it can be easily determined if the meshes are within the limits, and any sieve that falls without the limits should be rejected. Also, when the sieve shows that the meshes have been badly displaced by pulling, it should be discarded. If a sieve contains only a few imperfections, such as an occasional wider mesh, it can be corrected by soldering the wide meshes.

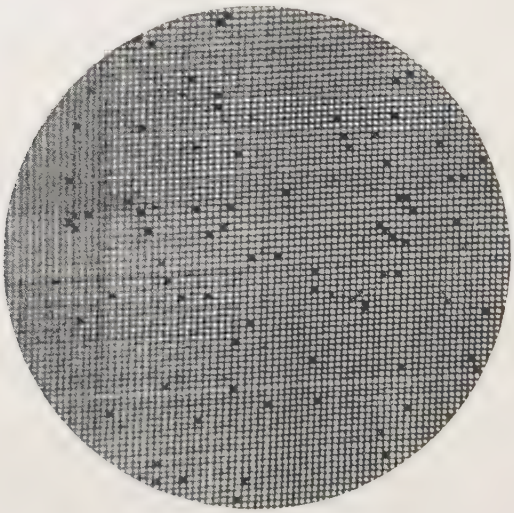

FIG. 5.—No. 200 Sieve. Enlargement 5.7 diameters.
Mesh by count 32,016 per square inch.

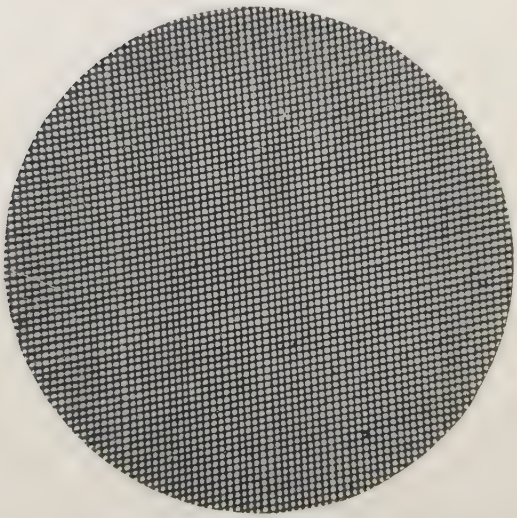

FIG. 6.—No. 200 Sieve. Enlargement 7. diameters.
Mesh by count 37,024 per square inch.

For some time past all sieves in use in our laboratory have been so examined, the best sieves accepted and corrected, and in this way we have been able to obtain concordant results, and results that can be duplicated at any time. An advantage of this method of testing of sieves is, that it in no way injures the sieve, and a large number of sieves may be obtained from the manufacturer, examined, and the best ones accepted. We have also made a practice of testing sieves and correcting them, with the result that such sieves, even when used by different parties, give results showing little variation.

DISCUSSION.

Mr. Richardson.

CLIFFORD RICHARDSON (By letter).—I have read with much interest the paper of Dr. Lazell. His conclusions are confirmed by my own experience, but I may be able to add something from the results of an investigation of the subject of sieves conducted for the information of the Committee "On Uniform Tests of Cement" of the American Society of Civil Engineers. Certain inquiries were made of Messrs. Howard and Morse, large manufacturers of sieves in Brooklyn, N. Y., who have furnished the New York Testing Laboratory with the most uniform ones that it has been able to find. The questions were as follows:

It is important that engineers, chemists and others using sieves for the determination of the fineness of materials, such as hydraulic cement, should be thoroughly informed as to the character of the wire cloth commercially available in this country and as to the possibility of obtaining a more satisfactory cloth than that now sold. May I ask you, therefore, to give me as much information as possible on the following points in regard to what is known as Nos. 50, 80, 100 and 200 mesh cloth:

1. Where are these cloths made?

2. What is the process of manufacture?

3. Can they all be made in the United States and at what increase in expense, if any?

4. Are cloths of the same mesh made of different sized wire?

5. What size of wire in numbers and in diameter in inches, by actual measurement, are used for each size cloth?

6. The ordinary cloth usually has the proper number of meshes to the inch in one diameter, but too few in the opposite. Why is this so?

7. Why are the sieves generally found in the trade so variable in size?

8. Would it be possible for you, and would you undertake to make 50, 80, 100 and 200 cloth and sieves to correspond to the following specifications?

Diameter of wire to be one-half the width of opening, that is to say: Mr. Richardson.

Mesh.	Mesh and Wire.	Diam of Wire.	Width of Opening.
50	.0200	.0067	.0133
80	.0125	.0042	.0083
100	.0100	.0038	.0067
200	.0050	.0017	.0033

9. Any other information or propositions which I can put before a number of gentlemen, who are interested in this subject, for their instruction?

To these interrogatories Messrs. Howard and Morse replied as follows:

1. Wire cloth of iron, steel, brass or copper, from the coarsest to No. 100 mesh, is made in this country, while finer meshes are imported from France, Germany and Scotland. We think the Scotch cloth is the best. Even 100 mesh can be imported at a lower cost than rate paid our weavers here will allow it to be produced.

2. Beginning with wire say 1-16 inch diameter, the mill draws down to smaller sizes until too hard to safely draw smaller; it is then annealed, when, its ductility being restored, it is drawn down finer, and then annealed, and the process repeated until the requisite size is obtained and it is given its final annealing, to render it fit for fabrication into cloth. The wire is delivered by the mill to the wire cloth manufacturers in skeins, which are rewound on spools according to the mesh required. Usually the process is as follows:

Taking, for instance, 100 mesh. We desire to put on a warp say 36 inches by 300 feet. This will make 3 cuts, each one hundred feet long. We estimate the weight, allowing for waste and "thrums," and taking a little over one-half the total weight, we divide this as equally as we may among the 100 spools, being careful that none are under weight. The spools are placed in a rack as closely as convenient; the wires from the spools are led through a device which prevents their crossing (and serves other purposes of a nature somewhat complicated to explain) to the "backbeam of loom." The 100 wires are what we term an "inch." They are tied together at end and hook over a bolt head in a slot which runs lengthwise of beam, which in our looms are about 5 feet circumference and 52 inches long. For 36-inch width we hook our first inch on peg 18 inches from centre; for 300 feet we would need put on 60 "rounds," *i. e.*, the beam (which is really a heavy solid cylinder) is turned 60 times, and the "lease" wire separating the contiguous wires alternately above and below the lease wire, is put in place and the beam turned up one more revolution to allow for distance from backbeam to face of loom.

The inch is then secured to another peg, which is firmly secured in the partition between the inches; these partitions forming grooves in

Mr. Richardson.

which the wires lay, and the bunch of 100 wires is then cut off and the second groove receives its 60 rounds, and so continued till the 36 grooves or inches are filled. This is a slow, tedious process.

However careful may be the winding of the spools, whatever device may be used for spool racks, yet the wire will catch and break, and it is necessary to repair every break before another round is turned up on the backbeam. If the spools run too freely, the wire comes off too fast, and a "bight" will draw into a kink and snap even comparatively heavy wire, or the bight will lie across other wires, and catching may snap a dozen or more. However, the warp being on the backbeam, one inch is taken off the peg, and the wires being separated by the "lease," are passed each one in the order in which it lies in the grooves, first through the "gears" or "heddles," and next through the "reed." The heddles consist of two frames about 8 to 10 inches high by the width of the loom in length, secured in a variety of ways; to these frames are attached twisted wires with an eye in the centre. For 100-mesh each frame must contain at least 50 of these twisted wires to each mesh. The 100 wires we have loosed from the backbeam are passed in their exact order alternately through back and front gear, or rather 50 passed through the eyes of the back gear, and the other 50 passed between the wires of the back gear through the eyes of the front.

These gears being operated by treadles, it is evident that when the back gear is down, and the front one is up from the normal line in which wires would tend to lie, that a "shade" or shed is formed, every alternate wire being in the upper, while the others are in the lower "shade" or "shed." The shade at the gears may be 3 inches, while at the face of the cloth it is nil, while in front of the reed when swung back as far as the "lay" will carry it, may be 2 inches. The lay or "beater" is hung overhead, and is provided with a groove in what is known as the bottom shell, and also in the top shell, which is removable and adjustable vertically to suit reeds of various heights, which are so placed in the shells as to have free lateral play, but very little in any other direction. All the inches being successively passed through the gears and reed, they are properly fastened to a "sacking" which leads from the face of the reed around a "breastbeam" down to the "clothbeam," on which it is wound up as the cloth is made.

The reed consists of a series of "splits" made of flat steel of peculiar temper. In a 100-mesh reed they would probably be about 3-16 inch wide, and the thickness of each split would be equal to a trifle less than the space between the wires of the cloth. They are compacted into reeds by a process of lacing, which must be very particularly done, as the split must stand square to plane of cloth, parallel, and evenly spaced, the spaces being a trifle more than the thickness of the wire which passes through them, and there must be exactly 100 in each and every inch. The warp being all ready to commence weaving, the weaver stepping on the treadle opens the shade and throws his shuttle through, catching it on the other side of the piece, the lay is brought up one blow, and he changes his

treadle and gives a second blow to place the shot. After throwing 100 shots and giving 200 blows he has completed one inch, when he proceeds to count it and thus discover whether he is driving the "woof" or "filling" up too hard or too lightly to place 100 transverse wires in one inch. Mr. Richardson.

Until fairly started his warp wires will be constantly breaking in fine cloth, and it is a constant contest of patience with unavoidable delays, until the last shot is thrown, though always worse at the beginning and gradually diminishing. After two or three inches have been made, the weaver gets the "blow" necessary to secure the required fineness in the mesh, and many become very expert and exact, that is, we thought it was exact until Mr. Richardson called our attention to many inaccuracies and defects. Being as good (perhaps better) than similar work from other factories, it sold, and we heard no complaint of inequalities until this cement testing question brought us face to face with a different problem.

3. We do not believe any American manufacturer could be induced to make the necessary outlay to produce cloth finer than 120, unless the field for its usefulness was very much enlarged, as the imported cloth at a much lower cost seems to answer every general purpose for which such cloth is used. Moreover, it might be necessary to import the workmen.

4. Cloth of same mesh can be made of many different sizes of wire, as witness pamphlet enclosed, but this is more nearly the truth theoretically than practically, where we go beyond 60 or 70 mesh.

5. The pamphlet above referred to will answer this in general. In particular we give answer to the four meshes specified by you:

Mesh.		Mesh.	Diam. of Wire.	Space.
No. 50	No. 35 O.E. Gauge Wire	.02	.009	.011
80	38 O.E. " "	.0125	.00575	.00675
100	40 O.E. " "	.01	.0045	.0055
200	42 1-2 B. & S. "	.005	.00235	.00265

6. If the reed be exact the cloth must have the proper number of holes one way, as it is governed by the reed. The reason that cloth sometimes has fewer holes the other way is that it is governed by the blow given by the weaver. If he can pass coarse cloth under the eye of the inspector, he gains the few missing shots in each inch and the same number of blows may in a day's work gain him 5 to 10 per cent more pay, but it is not so often the intention of the weaver so to deceive. A warp of 100 may be put on the loom in December and not be out until the following June. It is slow work. Consider the effects of various temperatures, and other causes which may affect a man's disposition meanwhile. Too gay or cheerful, you would be obliged to check his blow which would drive cloth too fine. In brisk cool weather, cloth would be driven up finer than in warm uncomfortable weather. Again, a fresh start in the morning means better cloth than that made in the later hours of the day. We have been accustomed to pass a coarseness not exceeding 5 per cent, *i. e.*, we would accept 80 x 76 as a square mesh. Again, the

Mr. Richardson.

wire is not even in either temper or size. Hard wire, or wire a trifle larger than it should be, will not "go to place" with the same blow that soft, proper gauge wire would require. We select all wire as carefully as possible, and though a great difference is not common in a single skein, yet the writer has gauged a skein of brass wire which has shown a full size difference when gauged at both ends. Not being wire-drawers, we are at a loss to account for this. It seems almost impossible that a die should be worn so perceptibly in drawing less than a mile of wire, and yet one end of the skein may be round while the other is elliptical in cross-section. These causes and others all tend to an irregularity of mesh which shows that the weaver is not entirely at fault.

To eliminate any question of nicety of touch and skill on the part of the weaver, fortunes have been sunk in experiments to produce an automatic loom, but the other causes remain, and though they affect the accuracy to a less degree in a power loom, yet they have a strong influence. We have power looms that will make the cloth exact, but cannot use them for anything finer than 20 or 30 mesh, and with only a medium weight wire. Another cause that may affect the mesh is the inequality of "temper," or in other words, speaking of other metal than steel, we should perhaps say "malleability," hardness or softness, but we have come to use the word "temper," however incorrect it may be, in reference to all metals used in fabrication of wire cloth.

The degree of heat to which wire is subjected, in the annealing process, may vary with the different charges; more than this, it may vary with the heat applied to the different skeins in a single charge, and more troublesome still it may be hotter one side of the skein than on the other. This makes serious inequalities in the "temper," and in consequence a variation in the mesh of the cloth in which it is used.

7. This question is fairly well covered in above, but in addition would state that each wire cloth manufacturer has ideas of his own as to what the trade requires; for instance, he may use 48 reed for 50 mesh, and have his cloth driven up to 44 the other way, so that he will furnish you on your call for 50-mesh a piece 48 x 44, while the manufacturer who gave you 50 x 50 on your call gives you a cloth that costs him more, both for material and labor, than the other.

Again, certain trades, notably the paper trade, requires cloth *not* driven up square, and 48 x 38 passes for 50-mesh, 68 x 52 for 70-mesh, and if this cloth goes through other channels, as a dealer's hands, he will sell a piece to any transient customer, say 58 x 46, and call it 60-mesh, and with entire innocence, for he bought it for 60-mesh.

Mill strainer cloth is another irregularity. It is made of very light wire, and not driven up, with any approach to accuracy. In fact, the low price obtained for it prohibits care in its manufacture. It is either woven by boys or on a power loom, which, as explained above, will not insure accuracy in fine meshes.

8. We, as explained in answer No. 3, would be willing to make any mesh of cloth up to and including 100-mesh (or even 120), but we could

not consider any proposition (at what would be considered reasonable to you) to make any finer mesh. Mr. Richardson.

Regarding your specifications: To make fine brass cloth with the diameter of wire one-half the width of opening, would result in a flimsy fabrication which in use would give you more unsatisfactory results than you now attain.

The individual wires would be of very little use, not only breaking very easily, but would push to one side or the other, two contiguous wires crowding each the neighboring wire, would separate and give space four times the size natural to the mesh. We find that in order to make fairly rigid cloth, it is necessary that the diameter of wire be about 80 per cent of space size, or practically as shown in our answer to No. 5. To make of lighter wire would increase cost, though we presume that is of minor importance, and yet must be considered. It would be difficult to make this perfectly clear, perhaps. To take sample of case of frequent occurrence: Our customers know that in the coarse grades of cloth, that in a certain mesh the price diminishes as diameter of wire decreases, and this is true up to about 60-mesh. We make this for stock of No. 36 O.E. Gauge Wire (.0075 inch). They order No. 37 in hopes of obtaining at lower price per square foot. The weight of 60 of No. 37 is 75¼ per cent as great as the weight of 60 of 36, and yet material for 37 costs about 40 per cent more per pound than 36. This difference becomes greater as we advance to the finer sizes. No. 200 mesh is made of .00235 inch wire (as near as the micrometer gauge will show it). The finest wire the writer ever saw was silver .002 inch in diameter, and this was shown as a curiosity rather than of any practical use.

It may be that ductility of brass is sufficient to make it practicable to draw it to .0017 inch. but we doubt it, and at what expense? 105,263 feet to one pound, *i. e.*, to draw one pound of .0017-inch brass wire, about 20 miles of wire must pass through the dies. This is getting down to fine work. It means about 16 days' work to one pound, for the finer the wire the more slowly it must be drawn. We do not mean weight, for that is evident, but as regards length. Imagine, too, the making of the die. Can one expect it to be round, square or true to any regular shape, or exactly accurate with regard to size?

Take even our 80-mesh, the wire wherein is .00575 inch in diameter, nearly 3½ times the diameter of the wire you specify for the 200-mesh, 11½ times as large in area of cross-section, consequently 11½ times as heavy in a given length, and contemplate the skill required to make a hole in a die which shall be round and with an exact diameter smaller than the hole in 100-mesh cloth. Consider the care necessary in drawing this wire, constant watching to note when the die is worn too large, and the whole manipulation until wire is woven into cloth and put into sieves, and there will be apparent reasons sufficient for the inaccuracies noted by you from time to time.

Up to 100-mesh, we can make a cloth as accurate as anyone in the trade; beyond that, we cannot control it. We will write parties in Glasgow

Mr. Richardson.

in a few days, and if we can learn anything of interest to you, will be glad to communicate it to you

We are willing to put on a short warp, say 36 inches by 100 feet each, Nos. 50, 80 and 100 mesh, guaranteeing that it shall be driven up square, *i. e.*, the 50 to between 48 and 50, the 80 to between 77 and 80, and the 100 to between 97 and 101, the wire carefully selected to conform to size given in answer No. 5, within 2 per cent of diameter, provided you will agree to find sale for same, at list price net, within one year of completion.

We are aware that we are undertaking a hard piece of work. The delays will be expensive; we shall expect to pay more than the usual price for the wire; every skein will need to be gauged at both ends, and if long, in the center as well; much of the wire will have to be discarded; the mill will contest our claims of inaccuracy; the cloth will have to be carefully and constantly watched, and the supervision will be onerous, but we are desirous of giving you all the satisfaction possible, though naturally without pecuniary loss to ourselves, and we, therefore, do not consider the whole cost of supervision in naming the above prices.

As to question No. 9. We have probably in this long and sometimes wandering explanation given you enough data to weary you in a proper selection, and the gentlemen to whom you speak as hearers, without adding to its burden at the present time.

From the preceding replies it is very evident where much of the difficulty in regard to the uniformity in sieves arises, and it is also very evident that 200-mesh sieves can not be made where the wire is half the diameter of the opening. As a matter of fact, in my laboratory it has been found that a better idea can be obtained of the fineness of the materials passed by a sieve according to the method of Mr. Allen Hazen,* measuring microscopically the average size of the largest particles passed by each sieve.

I can recommend highly the photographic method of counting sieves and of determining the accuracy of the weave. The accompanying photographs show a good and poor 200-mesh cloth. Bad cloth, however, as Dr. Lazell says, can be utilized by stopping out the more irregular portions with soft solder. For persons using sieves in large numbers, the best way of obtaining fine sieves which are uniform is to purchase entire bolts of cloth which is known to be of satisfactory count, and have sieves made from these as they are wanted. This is the method practiced in my laboratory.

*Reports Mass. State Board of Health, 1892, p. 541.

SOME ATTEMPTS TO LIMIT THE "PERSONAL EQUATION" IN CEMENT TESTING.

By W. A. Aiken.

When I had the pleasure of opening the discussion on cement at the meeting held here two years ago, and then spoke generally of the work inaugurated at the cement testing laboratory of the New York Rapid Transit Railroad Commissioners, I think I referred in touching upon our efforts generally to minimize as far as possible the baneful influence of the "personal equation" of the tester, to some special experiments just then commenced which I hoped would lead up to some interesting results. It is the data collated from those experiments which have now crystallized into a regular part of our work, but so far only for comparison, which I wish to lay before you now. We have for two years been regularly making up every tenth lot of cement submitted for use on our work, under what I call the "dry" process of briquette making, in addition to our usual method as practiced in laboratories generally. After much experimenting and numberless trials, which were going on two years ago, when I referred to this matter casually, I finally settled upon the method which we have rigidly adhered to ever since. Our gang molds are filled with dry cement in three layers, the two lower ones being tamped by three blows of a wooden mallet, and a tamping iron exactly fitting the molds, the top layer being simply put into place, pressed in and smoothed off with a small trowel after the molds have been filled. We adopted the three blows of the mallet because repeated experiments demonstrated that this number gave results, when the briquettes were broken, approximating the strength we desired in what we considered the most acceptable cement at seven-day period—fewer blows not giving such satisfactory results in every way, more blows developing abnormal strength at that period as well as at later stages. After the briquettes are finished, as far as filling the molds is concerned, the whole is put into storage tanks and there left to take up as much water as required. At the expiration of 24 hours all

the briquettes are ready to be taken from the molds, when those for the first period are immediately broken and the others stored in tanks. By careful weighing of a great many sets of briquettes it has been ascertained that 22 per cent of water by weight is taken up during the first immersion—this is just 1 per cent more than we generally use in ordinary practice, though therein when tempering we aim to obtain the same paste consistency always irrespective of the per cent of gage water; and while this does occasionally vary, from 20½ per cent to 22 per cent, working as we have with the output of one company's mills, this variation occurs so seldom that it may be ignored in calling our average gage water, 21 per cent. The absence of the influences, varying per cent of gage water, always possible with different operators, though not entering to any extent into even our tempered briquettes, and the actual tempering of the mixture with the subsequent molding of the briquettes by thumb pressure or tamping, is very pointedly shown by the breaks of these "dry" method briquettes.

First, the variation in weight of individual briquettes, our average results always being obtained from 10 breaks, as well as the variation in tensile strength of these 10 briquettes is markedly less than with the ordinary briquettes. The pronounced feature of our specifications, viz.: the per cent of gain in strength between 7 days and 28 days, which requirement to a greater or less extent is finding its way into other specifications since the publication of this clause under our contract No. 2 for the Manhattan-Brooklyn extension, is readily met in practically every instance under this "dry" method of manipulation, and while this is not applicable to sand mortar tests and does not approximate actual field conditions, even to the extent of briquettes ordinarily made, still as cement is not practically used neat, and laboratory results are only for comparison at best, any method giving such uniform results should claim attention.

Here follow some comparative results, the figures given for each period, being averages of 300 briquettes, representing over 50,000 barrels of cement irrespective of its acceptance or rejection.

ORDINARY WET BRIQUETTES.

7 days.	28 days.	3 mos.	6 mos.	1 year.
711 lbs.	791 lbs.	779 lbs.	774 lbs.	821 lbs.

Gain 11.1 per cent., 7 days to 28 days.

"DRY" METHOD BRIQUETTES.

7 days.	28 days.	3 mos.	6 mos.	1 year.
739 lbs.	888 lbs.	903 lbs.	863 lbs.	871 lbs.

Gain 20.1 per cent., 7 days to 28 days.

Of the lots of above total, which were accepted as approximating our gain requirement, the marked showing was as follows:

ORDINARY WET BRIQUETTES.

7 days.	28 days.	3 mos.	6 mos.	1 year.
705 lbs.	797 lbs.	788 lbs.	779 lbs.	863 lbs.

Gain 13.0 per cent., 7 days to 28 days.

"DRY" METHOD BRIQUETTES.

7 days.	28 days.	3 mos.	6 mos.	1 year.
710 lbs.	887 lbs.	912 lbs.	878 lbs.	897 lbs.

Gain 24.9 per cent., 7 days to 28 days.

Of the lots of first total rejected for marked failure to comply with our 15 per cent increase requirement, the results are as follows:

ORDINARY WET BRIQUETTES.

7 days.	28 days.	3 mos.	6 mos.	1 year.
764 lbs.	809 lbs.	785 lbs.	804 lbs.	695 lbs.

Gain 5.9 per cent., 7 days to 28 days.

"DRY" METHOD BRIQUETTES.

7 days.	28 days.	3 mos.	6 mos.	1 year.
816 lbs.	937 lbs.	903 lbs.	880 lbs.	792 lbs.

Gain 14.3 per cent., 7 days to 28 days.

which last results would have assured the acceptance of all the rejected cement, if the failure to show proper increase had been only reason for adverse action.

Examination will show that in every instance the "dry" method briquettes show the greater strength at every period, and while the above are averages, the uniformity of results in individual lots as referred to before, is very marked so that in most instances the lowest "dry" break is as good as the best "wet" break. These results are very surprising to me, and are incontrovertible evidence that the manipulation of the cement by the tester surely works detrimentally as far as obtaining most regular laboratory results.

DISCUSSION.

Mr. Page. L. W. PAGE.—I should like to say that, in 1898 I conducted an investigation on dry briquettes. There were several others working with me, and I found that the personal equation amounted to a good deal. In a series of fifty briquettes, one of the men got a variation of only 2.5 per cent.; other series varied much more. During the past winter I have been trying some further experiments along the same line with Mr. Johnson's ring-testing machine. I found that differences in pressure in molding the briquettes made very great differences in the results. Every brand of cement that I used seemed to require a different load to obtain anything like uniform results. This it seems to me is a serious objection to the method. However, I used steady pressure, and not impact in molding the briquettes.

Mr. Humphrey. RICHARD L. HUMPHREY (by letter).—Some time ago, when I first heard of Mr. Aiken's experiments with this "dry process" of making briquettes, I began a series of experiments. These experiments, while not so extensive as Mr. Aiken's, were, nevertheless, sufficiently elaborate to test the value of the method. The results I obtained far from confirm the views the author has just expressed.

In making tests of cement, the question of strength is not of paramount importance. It is far more important to secure uniform results than high tests. The object of our tests is to determine the relative value of different shipments. The neat cement tests are no criterion as to how the cement will act under the conditions under which it is used. The strength of mortar and concrete is dependent on the adhesive qualities. The question of adhesion is one of porosity, which is governed by the character of the material which forms the aggregates of the concrete or mortar. Adhesion is not the result of chemical combination, but is produced by the cement crystallizing and filling the pores in the surface of the aggregate, thus forming an anchorage which binds the mass together.

Mr. Humphrey.

The sand test affords a better indication of the quality of cement and its fitness for meeting the actual conditions. The dry method is very unsatisfactory with sand mortars, and I understand Mr. Aiken does not advocate its use. The process is therefore confined to neat cement tests only, a limitation which practically condemns it, as the sand tests are of more importance.

As to its use in the neat cement tests, I would remark, that if the cement is filled in the mold without compacting, the briquettes will not stand immersion in water, as the cement would float away. On the other hand the use of considerable pressure results in the formation of dense layers, particularly on the surface, which lift off after immersion. Owing to the difficulty of filling the molds, there was great variation in the density of the briquettes, and great variation therefore in the results of the tests.

Apropos of the filling of the molds, I would call attention to the old specifications, which required that Portland cement should weigh 110 or 112 pounds per Imperial bushel. It was an exceedingly difficult matter to so fill the bushel measure as to secure uniform results, and this was one of the reasons for its abandonment as a test. The same objections are applicable to filling briquette molds with neat cement.

I recall some briquettes made by this dry process in Mr. Aiken's laboratory in which there was a variation of 150 pounds. in the results of the seven-day tests.

My criticisms of this dry process are:

1. It is much slower than the usual methods.
2. It requires that the mold be immersed in water.
3. The mold cannot be turned over for finishing on both sides.
4. Greater care must be exercised in molding.
5. It is not adapted to mortar tests.

I find as a result of my observations that it requires greater skill, much more time, and that the results are far less uniform than those obtained by the wet paste prescribed by the Committee on Uniform Methods of Tests of Cement of the American Society of Civil Engineers.

Mr. Aiken.

W. A. AIKEN (by letter).—The records submitted by the author are so extensive that no series of mere experiments such as Mr. Humphrey refers to as having determined his conclusions can

Mr. Aiken.

in the slightest degree offset the deduction that in *neat* tests the "dry method" does eliminate two marked influences, controlling the so-called "personal equation" of the tester, viz., the determination of the gage-water percentage and the actual tempering of the paste as well as the molding of the briquettes.

No claim was made as to the adaptability of the method to sand-mortar tests. The reason is apparent without a dissertation upon the determining value of any cements. The "personal equation" in sand-mortar tests is very much less marked than in the manipulation of neat pastes, and, in fact, need not be considered when experienced testers are in comparison.

In describing the "dry method" the author assumed that any experienced operator would know that unless the dry cement was protected from the water's lifting tendency, it might float away. When the molds are properly protected there is neither any tendency to "float away" or to form dense surface layers as Mr. Humphrey states. Again, Mr. Humphrey's reference to the variation in density of his experimental briquettes is contrary to the author's reported experience that the variation in weight of these "dry method" briquettes is uniformly small.

Referring to Mr. Humphrey's five criticisms of the method, the author would reply:

1. The process is much more rapid than any other.

2. The mold immersion is the "essence" of the process.

3. The author always uses gang molds, with permanent bases, thus obviating the under-side finishing, which he considers objectionable under any circumstance.

4. The process requires much less care and experience than any other.

5. No claim was, or could be made, as to the process' application to such mortar tests.

In conclusion, no such records within the author's knowledge, covering such periods and a similar number of tests have ever been previously submitted, in comparison with regularly made briquettes of identically the same cement.

The results were only intended to show that if neat tests are used, this "dry method" does eliminate to a large extent the personal equation. No question was raised as to the relative value of neat-paste and sand-mortar tests.

CHARTER

OF THE

AMERICAN SOCIETY FOR TESTING MATERIALS.

To the Honorable the Judges of the Court of Common Pleas No. 2 in and for the City and County of Philadelphia: of March Term, 1902, No. 2056:

In compliance with the requirements of an Act of the General Assembly of the Commonwealth of Pennsylvania, entitled "An Act to Provide for the Incorporation and Regulation of Certain Corporations," approved the 29th day of April, A.D. one thousand eight hundred and seventy-four, and the supplements thereto, the undersigned, Henry M. Howe, Charles B. Dudley, Edgar Marburg, Robert W. Lesley, Mansfield Merriman, Albert Ladd Colby and William R. Webster, six of whom are citizens of Pennsylvania, having associated themselves together for the purposes hereinafter set forth, and desiring that they may be incorporated according to law, do hereby certify:

1. The name of the proposed corporation is the "AMERICAN SOCIETY FOR TESTING MATERIALS."

2. The corporation is formed for the Promotion of Knowledge of the Materials of Engineering, and the Standardization of Specifications and the Methods of Testing.

3. The business of the said corporation is to be transacted in Philadelphia.

4. The said corporation is to exist perpetually.

5. The names and residences of the incorporators are as follows:

HENRY M. HOWE, 27 West Seventy-third Street, New York.
CHARLES B. DUDLEY, Altoona, Pa.
EDGAR MARBURG, 517 South Forty-first Street, Philadelphia.
ROBERT W. LESLEY, 22 South Fifteenth Street, Philadelphia.
MANSFIELD MERRIMAN, South Bethlehem, Pa.
ALBERT LADD COLBY, South Bethlehem, Pa.
WILLIAM R. WEBSTER, "The Bartram," Thirty-third and Chestnut Streets, Philadelphia.

6. The management of the said corporation shall be vested in an Executive Committee, consisting of six (6) members, viz.: the Chairman, the Vice-Chairman, the Secretary, the Treasurer and two other members of the corporation, and such other officers as the corporation may from time to time appoint.

7. The corporation has no capital stock, and the members thereof shall be composed of the subscribers and their associates and of such persons as may from time to time be admitted by vote in such manner and upon such requirements as may be prescribed by the By-Laws. The corporation shall nevertheless have power to exclude, expel or suspend members for just or legal cause, and in such legal manner as may be ordained and directed by the By-Laws.

8. The By-Laws of this corporation shall be admitted and taken to be its laws subordinate to the statute aforesaid; this Charter; Constitution and Laws of the Commonwealth of Pennsylvania, and the Constitution of the United States; they shall be altered and amended as provided for by the By-Laws themselves; and shall prescribe the powers and functions of the Executive Committee herein mentioned and those to be hereafter elected, the times and places of meetings of the Committee and this corporation; the number of members who shall constitute a quorum at the meetings of the corporation, and of the Committee; the qualifications and manner of electing members; the manner of electing officers; and the powers and duties of such officers; and all other concerns and internal arrangements of the said corporation.

Witness our hands and seals this twenty-first day of March, A.D. 1902.

(Signed) EDGAR MARBURG,
R. W. LESLEY,
WM. R. WEBSTER,
MANSFIELD MERRIMAN,
ALBERT LADD COLBY.

BY-LAWS.

Article I.

MEMBERS.

Section 1. Any person, corporation or technical society holding membership in the International Association for Testing Materials is eligible for membership.

Sec. 2. Any person, corporation or society can become a member of this Society and of the International Association for Testing Materials simultaneously upon being proposed by two members of this Society and being approved by its Executive Committee.

Sec. 3. Any member who subscribes annually the sum of fifty dollars ($50) toward the general funds of the Society shall be designated a Contributing Member, his rights and privileges as a member remaining unchanged.*

Sec. 4. Applications for membership and resignation from membership must be transmitted in writing to the Secretary.

Article II.

OFFICERS AND THEIR ELECTION.

Section 1. The officers shall be a President, Vice-President, Secretary and Treasurer.

Sec. 2. The offices of Secretary and Treasurer shall be held by the same person.

Sec. 3. These officers shall be elected by letter-ballot, at the Annual Meeting, and shall hold office for two years.

Sec. 4. The Executive Committee shall consist of these officers and also the last past-President and three members, two being elected by letter-ballot at each Annual Meeting in the odd years and one at each Annual Meeting in the even years.

Sec. 5. The President shall be, *ex officio*, the nominee for American Member of the Council of the International Association.

Sec. 6. The Secretary shall receive a salary to be fixed by the Executive Committee.

* The Executive Committee has ruled that Contributing Members shall be exempt from the regular membership dues.

Sec. 7. The officers and members of the Executive Committee of this Society to hold office until the next election under these By-Laws, shall be as follows: To hold office for two years—President, Charles B. Dudley; Vice-President, R. W. Lesley; Secretary-Treasurer, Edgar Marburg; members of the Executive Committee, Henry M. Howe and James Christie. To hold office for one year—members of the Executive Committee, Albert Ladd Colby and John McLeod.

Sec. 8. The above officers and members of the Executive Committee, as well as all succeeding officers and members of the Executive Committee elected under these By-Laws, shall serve for the respective terms to which they shall have been elected, or until their successors shall have been duly elected.

Sec. 9. The Executive Committee shall have the power to fill any vacancies occurring in their number by death, resignation or otherwise.

Sec. 10. The election of officers and members of the Executive Committee shall be by letter-ballot. The Executive Committee, before each Annual Meeting, shall appoint a Nominating Committee, whose duty it shall be to nominate a full list of officers. The list of nominations so made shall be submitted to the membership not more than eight (8) nor less than four (4) weeks before the coming Annual Meeting.

Further nominations, signed by at least ten (10) members, may be submitted to the Secretary in writing at least four (4) weeks before the Annual Meeting, and such nominations shall also be submitted to the membership on the official ballot.

Article III.

meetings.

Section 1. The Society shall meet annually. The time and place of each meeting shall be fixed by the Executive Committee.

Sec. 2. Special meetings may be called whenever the Executive Committee shall deem it necessary, or upon the request in writing to the President of twenty-five (25) members.

Article IV.

dues.

Section 1. The fiscal year shall commence on the first of January, and all dues shall be payable in advance.

Sec. 2. The annual dues of each member shall be $5.00. Of this amount $1.50 shall be transmitted by the Secretary to the International Association for Testing Materials. The remainder shall be applied to the treasury of the Society.

Sec. 3. Any member of the Society whose dues shall remain unpaid for the period of one year shall forfeit the privileges of membership. If he neglects to pay his dues within thirty days thereafter, and after notification from the Secretary, his name may be stricken from the roll of membership by the Executive Committee.

Article V.

Amendments.

Section 1. Proposed Amendments to these By-Laws, signed by at least three members, must be presented in writing to the Executive Committee at least four weeks before the next Annual Meeting. In the notices for this meeting the proposed Amendments shall be printed. At the Annual Meeting the proposed Amendment may be discussed and amended and may be passed to letter-ballot by a two-thirds vote of those present.

If two-thirds of the votes obtained by letter-ballot are in favor of the proposed Amendment, it shall be adopted.

Sec. 2. The Executive Committee is authorized to number the Articles and Sections of the By-Laws to correspond with any changes that may be made.

RULES GOVERNING THE EXECUTIVE COMMITTEE.

1. Regular meetings shall be held on the first Saturday in January, April, July and October. Four members shall constitute a quorum.

At each meeting the Secretary shall report the names of all new members and of members who have resigned during the previous quarter, and shall present a financial statement.

At the January meeting the Secretary shall report the names of all members whose dues are unpaid.

The accounts of the Secretary shall be duly audited at the middle and close of each fiscal year, and the report of the auditors shall be presented in writing at the July and January meetings.

2. Special meetings may be held at any time at the call of the President, or upon the written request of four members of the Executive Committee. The notice for such meetings shall be mailed by the Secretary at least one week in advance of the meeting, and the business shall be stated in the notice.

3. The Secretary shall transmit to the International Association within five days after the first day of January, April, July and October $1.50 for each member whose dues were paid in the previous quarter together with the names of those members.

No other expenses shall be paid except on vouchers certified to be correct by the Chairman of the Committee on Finance, or a member thereof designated by the Chairman.

GENERAL INFORMATION.

International Association for Testing Materials.

Historical.—The International Association for Testing Materials had its origin in a conference of a small group of workers in experimental engineering held in Munich in 1882, at the instance chiefly of the late John Bauschinger. Meetings on a larger scale were subsequently held in Dresden (1884), Berlin (1886), Munich (1888), Vienna (1893) and Zurich (1895). At the Zurich Congress the International Association for Testing Materials was formally organized, the Second Congress was held at Stockholm in 1897, the Third Congress met at Buda-Pesth in 1901,* and the Fourth Congress will assemble at St. Petersburg August 18–25, 1905.

Membership.—The membership, according to the latest official report (November, 1904), is distributed as follows: United States, 580;† Germany, 367; Russia, 357; Austria, 193; France, 154, Switzerland, 82; Hungary, 80; Belgium, 53; England, 52; Italy, 50; Sweden, 49; Denmark, 48; Holland, 45; Norway, 44; Roumania, 18; Spain, 14; Portugal, 11; Servia, 5; Australia, 4; Luxemburg, 4; Brazil, 2; Argentine Republic, 1; Chili, 1; Japan, 1. Total, 2,215, representing 24 countries.

Objects.—The objects of the Association, as set forth in its By-Laws,‡ are: "The development and unification of standard methods of testing; the investigation of the technically important properties of the materials of construction and other materials of technical importance, and also the perfecting of apparatus used for that purpose."

The important subject of specifications has, however, also been included within the scope of the Association's activity. Thus. International Committee No. 1 has been charged to report on the following problem: "On the basis of existing specifications, to seek methods and means for the introduction of international specifications for testing and inspecting iron and steel of all kinds."

* The Third Congress, originally scheduled for 1900, to be held at Paris during the Exhibition, was abandoned in order not to conflict with the International Testing Congress, conducted under French auspices.

† The American membership is now (January, 1905) 603.

‡ These By-Laws are given in full on pp. 633–635.

Again, in pursuance of American initiative at the Buda-Pesth Congress (1901), Committee No. 1 has been enlarged by the addition of three American members, with a view of reporting on "Standard International Specifications for Cast Iron and Finished Castings," and Committee No. 22 has been instructed to report "On the Feasibility of the Establishment of Standard International Specifications for Cements."

Administration.—The affairs of the Association are administered by a Council, consisting of the President and one representative (member of Council) from each country having a membership of twenty (20) or more.

Methods.—The original plan was to conduct investigations almost exclusively through the agency of international committees. These committees proved unwieldy, however, by reason of their large membership, with the added difficulties arising from geographical separation and differences of language. In pursuance of resolutions at the Buda-Pesth Congress (1901) the Council has discharged some of these committees, reassigning the problems in part to individual referees.* In the case of questions of direct international concern the original international committees are continued.

At the international congresses the reports of these committees as well as individual contributions by members are presented and discussed.

Publications.—On May 5, 1896, the International Council effected an arrangement with the publishers of *Baumaterialenkunde*† (Materials of Construction) by which that journal became the official organ of the Association. Since July, 1896, this journal has published the Proceedings of Congresses and other official matter in German and French. The fact that the Association did not furnish printed Proceedings to members free of charge, and that no provision had been made for translation into English, gave rise to no little dissatisfaction. At the Buda-Pesth Congress (1901) the International Council was accordingly authorized to perfect a new arrangement by which all official matter is to be

* For complete list of problems, committees and referees, see pp. 636–643.

† *Baumaterialenkunde:* Published bi-weekly at Stuttgart, Germany, in German and French. Regular subscription price $3.50 per annum; special terms to members of the International Association for Testing Materials, $2.50 per annum. Address: Staehle & Friedel, No. 57 Tuebinger Street, Stuttgart, Germany.

published in three separate editions (German, English and French) and sent free of charge to every member of the Association in whatever language may be preferred.

Organization of the American Members of the International Association.

Historical.—With a view of bringing the members of like nationality into closer relations among themselves, and in order to simplify the management and render the work of the Association more effective, it was decided at the Stockholm Congress (1897) to encourage the consolidation of the membership in the various countries into separate national organizations. In pursuance of this action the American members met in Philadelphia on June 16, 1898, and organized under the name of the "American Section of the International Association for Testing Materials."

In March, 1902, the Executive Committee of the American Section applied for a Charter under the laws of the State of Pennsylvania for purposes of incorporation under the proposed new name of the "American Society for Testing Materials." This Charter was duly granted, and at the Fifth Annual Meeting, held at Atlantic City, N. J., it was unanimously adopted on June 12, 1902.

Objects.—The objects of the Society are essentially identical with those of the International Association, with which it stands in direct organic relation, both through its membership in the same as a body, and through the prescribed individual membership on the part of every one of its members.

As stated in the Charter: "The corporation is formed for the promotion of knowledge of the materials of engineering, and the standardization of specifications and the methods of testing."

Representation on the International Council.—The American members are entitled to one representative on the International Council. By the new Statutes of the Association (1901): "the members of Council shall be proposed by the members of each country; their final appointment being confirmed by the Congress." According to the By-Laws of the American Society the President becomes, "*ex officio*, the nominee for American Member of the Council of the International Association."

Meetings.—The Society meets annually at a time and place fixed by the Executive Committee. Special meetings may also be called in accordance with the provisions of the By-Laws.

Annual meetings have been held in past years as follows:

First Annual Meeting, Philadelphia, Pa., House of Engineers' Club of Philadelphia, August 27, 1898.

Second Annual Meeting, Pittsburg, Pa., Rooms of Engineers' Society of Western Pennsylvania, August 15, 16, 1899.

Third Annual Meeting, New York, N. Y., House of American Society of Mechanical Engineers, October 25, 26, 27, 1900.

Fourth Annual Meeting, Niagara Falls, N. Y., International Hotel, June 29, 1901.

Fifth Annual Meeting, Atlantic City, N. J., Hotel Traymore, June 12, 13, 14, 1902.

Sixth Annual Meeting, Delaware Water Gap, Pa., Hotel Kittatinny, July 1, 2, 3, 1903.

Seventh Annual Meeting, Atlantic City, N. J., Hotel Traymore, June 16, 17, 18, 1904.

Membership.—The number of American members at the time of the organization meeting in 1898 was 70. The membership reported at the successive annual meetings was as follows: (1899) 128, (1900) 160, (1901) 168, (1902) 175, (1903) 349, (1904) 485, and it is now (January, 1905), 603.

Methods.—The operations of the Society are conducted in part under the auspices of the International Association and in part independently.

The number of American representatives on international committees is fixed by the International Council. These American sub-committees are authorized, however, to increase their number at pleasure, subject always to the approval of the Executive Committee of the American Society. The sense of these enlarged sub-committees on all questions is determined by majority vote; but on the international committees the representation and the number of votes allowed remain as originally fixed by the International Council.

The American Society appoints other committees at its discretion entirely independently of the International Association. On committees concerned with subjects involving commercial interests, the policy is to accord equal numeric representation to engineers, scientists and representatives of consumers on the one hand, and to manufacturers or their representatives on the other. The permanent chairmanship must be held by a member belonging to the former class, duly elected by the committee.

The Committees of the American Society are now as follows:

A. On Standard Specifications for Iron and Steel.

B. On Standard Specifications for Cast Iron and Finished Castings.

C. On Standard Specifications for Cement.
D. On Standard Specifications for Paving and Building Brick.
E. On Preservative Coatings for Iron and Steel.
F. On Heat Treatment of Iron and Steel.
G. On the Magnetic Properties of Iron and Steel.
H. On Standard Tests for Road Materials.
I. On Reinforced Concrete.
J. On Standard Specifications for Foundry Coke.
K. On Standard Methods of Testing.
L. On Standard Specifications and Tests for Sewer Pipe.
M. On Standard Specifications for Staybolts.
N. On Standard Tests for Lubricants.
O. On Uniform Speed in Commercial Testing.
P. On Fire-proofing Materials.
Q. On Standard Specifications for the Grading of Structural Timber.
R. On Boilers.

Publications.—The publications of the Society appeared originally at irregular intervals in the form of bulletins. Twenty-eight (28) bulletins, containing a total of 266 pages, were thus issued. In 1902 it was decided to publish the Proceedings thereafter in the form of annual volumes. In passing to this new plan of publication the twenty-eight bulletins previously issued were counted collectively as Volume I. The first of the annual volumes, designated Volume II and issued in 1902, contains 388 pages. Volume III, issued in 1903, contains 490 pages.*

A notable work accomplished by the Society is the framing, by the American Branch of International Committee No. 1 (enlarged for this purpose to thirty-four members), and the adoption in August, 1901, by letter-ballot of the Society, of Standard Specifications on (1) Structural Steel for Bridges and Ships, (2) Structural Steel for Buildings, (3) Open-hearth Boiler Plate and Rivet Steel, (4) Steel Rails, (5) Steel Splice Bars, (6) Steel Axles, (7) Steel Tires, (8) Steel Forgings, (9) Steel Castings, (10) Wrought Iron. These ten Standard Specifications are published separately in the order given as Bulletins Nos. 8 to 16 inclusive, and Bulletin No. 24.

Committee B, on Standard Specifications for Cast Iron and Finished Castings prepared specifications for the following products which were adopted as Standard Specifications by letter-ballot in November, 1904, (1) Cast-Iron Pipe and Special Cast-

* For price-list of publications, see page 631.

ings, (2) Foundry Pig Iron, (3) Malleable Castings, (4) Locomotive Cylinders.

Standard Specifications for Cement, prepared by Committee C, were adopted by letter-ballot in November, 1904.

Proposed Standard Specifications for other materials and finished products are in course of preparation by various committees.

OFFICERS

OF THE

AMERICAN SOCIETY FOR TESTING MATERIALS.

PRESIDENT,
CHARLES B. DUDLEY.

VICE-PRESIDENT,
R. W. LESLEY.

SECRETARY-TREASURER,
EDGAR MARBURG.
Office: University of Pennsylvania, Philadelphia, Pa.

MEMBERS OF THE EXECUTIVE COMMITTEE:

Term Expiring in 1905.

ALBERT LADD COLBY, JOHN MCLEOD.

Term Expiring in 1906.

JAMES CHRISTIE, HENRY M. HOWE.

STANDING COMMITTEES.

COMMITTEE ON FINANCE.

JOHN MCLEOD, *Chairman*, ALBERT LADD COLBY,
R. W. LESLEY.

COMMITTEE ON MEMBERSHIP.

JAMES CHRISTIE, *Chairman*, R. W. LESLEY,
EDGAR MARBURG.

COMMITTEE ON PUBLICATIONS.

HENRY M. HOWE, *Chairman*, ALBERT LADD COLBY,
EDGAR MARBURG.

LIST OF MEMBERS

OF THE

AMERICAN SOCIETY FOR TESTING MATERIALS.

Affiliated with the International Association for Testing Materials.

Note.—Contributing members are distinguished by an asterisk.

ELECTED.

1904. ABBOTT, L. S. Industrial Engineer, 770 West Adams Street, Chicago, Ill.

1902. ACKERMAN, ERNEST R. President, Lawrence Cement Company, 1 Broadway, New York, N. Y.

1904. ACKERMAN, IRA J. Chemist for Pratt and Lambert, 79–97 Tonawanda Street, Buffalo, N. Y.

1904. ADAMS, HUGH W. Eastern Agent, Sloss-Sheffield Steel and Iron Company, 15 Beekman Street, New York, N. Y.

1898. AERTSEN, GUILLIAEM. General Manager, Latrobe Steel Company, 1200 Girard Building, Philadelphia, Pa.

1904. AIKEN, CHARLES W. Consulting Engineer, 82 Washington Street, New York, N. Y.

1902. AIKEN, W. A. General Inspector of Material, Rapid Transit Railroad Commission of New York, 613 Empire Building, Pittsburg, Pa.

1902. *AJAX METAL COMPANY. G. H. Clamer, Second Vice-President and Secretary, 46 Richmond Street, Philadelphia, Pa.

1904. ALLCOTT, F. L. Engineer of Tests, Chicago, Milwaukee and St. Paul Railway, Milwaukee, Wis.

1903. ALLEN, A. W. Superintendent, Steel Department, Pencoyd Iron Works, 267 Rochelle Avenue, Philadelphia, Pa.

1902. ALLEN, FRANCIS B. Mechanical Engineer; First Vice-President, Hartford Steam Boiler Inspection and Insurance Company, Hartford, Conn.

1904. ALLEN, WALTER H. Civil Engineer, U. S. Navy, Navy Yard, New York, N. Y.

1902. AMERICAN BRIDGE COMPANY. C. C. Schneider, Consulting Engineer, Fifteenth and Chestnut Streets, Philadelphia, Pa.

1904. AMERICAN BUREAU OF INSPECTION AND TESTS. E. B. Wilson, Secretary and Treasurer, 930 Monadnock Block, Chicago, Ill.

ELECTED.

1898. American Foundrymen's Association. Richard Moldenke, Secretary, Watchung, N. J.

1904. American Machinist. Fred. J. Miller, Editor, 63 Park Row, New York, N. Y.

1897. American Society of Mechanical Engineers. F. R. Hutton, Secretary, 12 West Thirty-first Street, New York, N. Y.

1900. American Steel and Wire Company. F. H. Daniels, Chief Engineer, Worcester, Mass.

1899. Anderson, Frederick Paul. Dean of School of Mechanical Engineering, State College of Kentucky, Lexington, Ky.

1896. Anderson, J. W. Carbon Steel Company, Pittsburg, Pa.

1897. Anderson, R. Wilson. Superintendent, Open-Hearth Plant, Carbon Steel Company, Pittsburg, Pa.

1904. Angus, W. F. Engineer, Montreal Steel Works, Limited, Montreal, Canada.

1902. Arnold, Charles E. Chief Chemist, Dominion Iron and Steel Company, Sydney, C. B., Canada.

1903. Atkinson, Edward. Director, Insurance Engineering Station, 31 Milk Street, Boston, Mass.

1904. Averill, F. L. Civil Engineer, Washington Representative of Robert W. Hunt and Company, Room 220, Colorado Building, Washington, D. C.

1904. Aylett, Phillip. Bridge Engineer, Seaboard Air Line Railway, Portsmouth, Va.

1902. Bailey, J. B. Treasurer and General Manager, Central Iron and Steel Company, Harrisburg, Pa.

1903. Bakenhus, R. E. Civil Engineer, United States Navy, Naval Training Station, Newport, R. I.

1903. Baker, Ira O. Professor of Civil Engineering, University of Illinois, Champaign, Ill.

1904. Baker and Co., W. E. Engineers, 27 William Street, New York, N. Y.

1904. Baldwin, Stephen W. Mechanical Engineer, associated with Pennsylvania Steel Company and Maryland Steel Company, 71 Broadway, New York, N. Y.

1904. Barber Asphalt Paving Company. J. L. Rake, General Agent, Land Title Building, Philadelphia, Pa.

1898. Barbour, Frank A. Civil Engineer, Snow and Barbour, 1121 Tremont Building, Boston, Mass.

ELECTED.

1904. BARNES, CHARLES B. Chief Draftsman, C. D. Pfister and Vogel Leather Company, 3006 Mount Vernon Avenue, Milwaukee, Wis.

1904. BARNSLEY, GEORGE T. Resident Engineer, in Charge of Construction, Wabash Pittsburg Terminals, Wabash Building, Pittsburg, Pa.

1904. BASQUIN, OLIN H. Associate Professor of Physics, Northwestern University, Evanston, Ill.

1903. BASSETT, WILLIAM H. Chemist in charge of Laboratories, Coe Brass Manufacturing Company, Torrington, Conn.

1903. BATEMAN, F. W. Civil Engineer, Clinton, Mass.

1904. BECK, WESLEY J. Superintendent, Electrical Department, American Rolling Mill Company, Middletown, Ohio.

1903. BECKETT, JAMES A. General Superintendent, Walter A. Wood Mower and Reaper Company, Hoosick Falls, N. Y.

1904. BEEBE, T. E. Superintendent, International Cement Company, Elizabeth, Pa.

1903. BENTLEY, ROBERT. Secretary and General Manager of the Ohio Iron and Steel Company, Lowellville, O.

1902. BERGER, BERNT. Civil Engineer, Assistant Engineer to Theodore Cooper, 45 Broadway, New York, N. Y.

1904. BERGQUIST, J. G. Superintendent, Cement Plant, Illinois Steel Company, Chicago, Ill.

1904. BERLE, KORT. Chief Structural Engineer, Supervising Architect's Office, Washington, D. C.

1903. BERRALL, JAMES. Civil Engineer, Bond Building, Washington, D. C.

1898. BETHLEHEM STEEL COMPANY. E. O'C. Acker, Assistant General Superintendent, South Bethlehem, Pa.

1904. BETTS, H. S. Testing Engineer, Bureau of Forestry, Washington, D. C.

1904. BIRD, ROBERT M. Superintendent, Treatment Department, Bethlehem Steel Company, 433 Brodhead Avenue, South Bethlehem, Pa.

1896. BISSELL, GEORGE W. Professor Mechanical Engineering, Iowa State College, Ames, Iowa.

1903. BIXBY, W. H. Colonel, Corps of Engineers, United States Army, address unknown.

1904. BLACK, ADOLPH. Instructor in Civil Engineering, Columbia University, New York, N. Y.

1904. BLANCH, JOSEPH C. Superintendent, Blanchite Process Paint Company, 42 Broadway, New York, N. Y.

ELECTED.

1902. Bliss, Collins P. Professor of Mechanical Engineering, and Director of Testing Laboratory, New York University, University Heights, New York, N. Y.

1903. Bocking, Rudolph. Halbergerhutte, Post Brebach, Germany.

1903. Boller and Hodge. Consulting Engineers, 1 Nassau Street, New York, N. Y.

1902. Bonzano, A. President, Bonzano Rail-Joint Company, 331 South Eighteenth Street, Philadelphia, Pa.

1896. Booth, Garrett and Blair. Engineers and Chemists, 406 Locust Street, Philadelphia, Pa.

1904. Bostwick, W. A. Metallurgical Engineer, Carnegie Steel Company, Pittsburg, Pa.

1904. Bowman, Austin Lord. Consulting Engineer; Bridge Engineer, Central Railroad Company of New Jersey, 29 Broadway, New York, N. Y.

1902. Boynton, C. W. Cement Department, Illinois Steel Company, 244 Central Avenue, Austin, Ill.

1900. Braine, L. F. General Manager, Continuous Rail-Joint Company, Newark, N. J.

1898. Bramwell, Joseph W. 4931 Rubicam Avenue, Germantown, Philadelphia, Pa.

1904. Bregowsky, Ivan M. Metallurgist, Crane Company, 51 Judd Street, Chicago, Ill.

1899. Broadhurst, W. H. Chemist, Department of Public Works, Municipal Building, Brooklyn, N. Y.

1903. Brown, Charles Carroll. Editor, Municipal Engineering Magazine, 408 Commercial Club Building, Indianapolis, Ind.

1904. Brown, John G. Manager, Unit Concrete-Steel Frame Company, 1416 Commonwealth Building, Philadelphia, Pa.

1904. Brown, Samuel A. Inspector of Cement, Philadelphia Rapid Transit Company, 1526 South Thirteenth Street, Philadelphia, Pa.

1903. Brunner, John. Assistant General Superintendent, Illinois Steel Company, 1732 Chicago Avenue, Evanston, Ill.

1903. Buckley, E. R. Director, Missouri Bureau of Geology and Mines, State Geologist, Rolla, Mo.

1903. Budd, H. I. Commissioner of Public Roads of State of New Jersey, Mt. Holly, N. J.

ELECTED.

1904. BUNNELL, F. O. Engineer of Tests, Chicago, Rock Island and Pacific Railway, Forty-seventh Street and Wentworth Avenue, Chicago, Ill.

1902. BURDETT, F. A. Civil Engineer, 3 East Thirty-third Street, New York, N. Y.

1903. BURNHAM, RAYMOND. Associate Professor Experimental Engineering, Armour Institute of Technology, Chicago, Ill.

1899. BURR, WILLIAM H. Professor of Civil Engineering, Columbia University, New York, N. Y.

1903. BUZZI, P. D. Superintendent of Engineering Laboratory, Tacon 3, Havana, Cuba.

1904. CAHALL, W. H. Superintendent, Boiler Department, 706 Lake Avenue, Racine, Wis.

1904. CAIRNS, EDWARD T. General Inspector, Improved Risk Department, The North British and Mercantile Insurance Company, 159 La Salle Street, Chicago, Ill.

1902. CAMBIER, JACOB. Chemist, Colorado Fuel and Iron Company, 910 Spruce Street, Pueblo, Colo.

1899. *CAMBRIA STEEL COMPANY. George E. Thackray, Structural Engineer, Johnstown, Pa.

1896. CAMPBELL, H. H. Superintendent and General Manager, The Pennsylvania Steel Company, Steelton, Pa.

1903. CAMPBELL, WILLIAM. Metallurgist, Barnard Fellow, Columbia University, New York, N. Y.

1898. CAPP, JOHN A. Engineer, Testing Laboratory, General Electric Company, Schenectady, N. Y.

1898. *CARNEGIE STEEL COMPANY. John McLeod, Assistant to President, Pittsburg, Pa.

1903. CARNEY, F. D. Assistant Superintendent, Pennsylvania Steel Company, Steelton, Pa.

1902. CARPENTER, LOUIS G. Professor of Civil and Irrigation Engineering, and Director of Experiment Station, Fort Collins, Colo.

1895. CARPENTER, ROLLA C. Professor Experimental Engineering, Cornell University, 31 Eddy Street, Ithaca, N. Y.

1903. CARPENTER STEEL COMPANY, THE. George W. Sargent, Metallurgist, Reading, Pa.

1902. CARR, LOVELL H. General Sales Agent, The Edison Portland Cement Company, 71 Broadway, New York, N. Y.

ELECTED.

1904. Carter, J. G. Inspector of Sand and Cement, Washington Aqueduct, 2728 Pennsylvania Avenue, N. W., Washington, D. C.

1899. Carter, Robert A. President, Monongahela Iron and Steel Company, Box 215, Pittsburg, Pa.

1903. Cartlidge, C. H. Bridge Engineer, Chicago, Burlington and Quincy Railroad, 209 Adams Street, Chicago, Ill.

1902. *Central Iron and Steel Company. James B. Bailey, Treasurer and General Manager, Harrisburg, Pa.

1904. Cheesman, Frank P. National Paint Works, 92 William Street, New York, N. Y.

1898. Christie, James (*Member of Executive Committee*). Chief Mechanical Engineer, American Bridge Company, Pencoyd, Pa.

1900. Churchill, Charles S. Chief Engineer, Norfolk and Western Railway, Roanoke, Va.

1900. Clark, F. H. Mechanical Engineer, Chicago, Burlington and Quincy Railroad, 209 Adams Street, Chicago, Ill.

1904. Clarkson Memorial School of Technology, Thomas S. William S. Aldrich, Director, Potsdam, N. Y.

1904. Clifton, Charles H. First Assistant, Philadelphia Municipal Testing Laboratory, 318 City Hall, Philadelphia, Pa.

1899. Colby, Albert Ladd (*Member Executive Committee*). International Nickel Company, 43 Exchange Place, New York, N. Y.

1899. Colby, J. Allen. Inspecting Engineer, Witherspoon Building, Philadelphia, Pa.

1904. Colles, George W. Consulting Mechanical and Electrical Engineer, 408 Alh[illegible]mbra Building, Milwaukee, Wis.

1900. Colorado Fuel and Iron Company. C. S. Robinson, General Manager, Iron Department, Denver, Colo.

1900. Condron, T. L. Resident Engineer, Pittsburg Testing Laboratory, 1750 Monadnock Building, Chicago, Ill.

1904. Conlin, Frederick. General Manager, Bethlehem Foundry and Machine Company, Lehigh Foundry Company, 355 Market Street, Bethlehem, Pa.

1904. Connor, Charles E. Assistant Inspector of Buildings of District of Columbia, The Farragut, Washington, D. C.

1904. Conradson, P. H. Chief Chemist, Galena Signal Oil Company, Franklin, Pa.

1903. Cook, Edgar S. President, Warwick Iron and Steel Company, Pottstown, Pa.

ELECTED.

1899. CORTHELL, E. L. Civil Engineer, 1 Nassau Street, New York, N. Y.

1902. COSBY, SPENCER. Captain, Corps of Engineers, U. S. Engineer Office, Mobile, Ala.

1903. COWEN, HERMAN C. Superintendent, Catskill Cement Company, Smith Landing, Greene County, N. Y.

1904. CROWELL, BENEDICT. Mining Engineer, 731 Williamson Building, Cleveland, O.

1903. CROXTON, H. A. President, Massillon Iron and Steel Company, Massillon, O.

1899. CRUIKSHANK, BARTON. Consulting Engineer, 1813 West Genesee Street, Syracuse, N. Y.

1904. CUMMINGS, ROBERT A. Consulting and Contracting Engineer, 609 House Building, Pittsburg, Pa.

1904. CUSHMAN, ALLERTON S. Chemist, Road Material Laboratory, U. S. Department of Agriculture, Washington, D. C.

1903. DABBS, HAROLD M. L. J. McCloskey and Company, Thirtieth and Locust Streets, Philadelphia, Pa.

1900. DAVIDSON, GEORGE M. Engineer of Tests, Chicago and Northwestern Railroad, Chicago, Ill.

1904. DAVIS, A. P. Assistant Chief Engineer, United States Geological Survey, Washington, D. C.

1904. DAVIS, CHANDLER. Department of Docks and Ferries, Pier "A," North River, New York, N. Y.

1904. DAVIS, NATHAN H. President, Diamond State Car Steel Company, Davis Pressed Steel Company, Wilmington, Del.

1903. DAVIS, WILLIAM R. Chief Bridge Designer, State Engineer's Office, Albany, N. Y.

1904. DAVIS, WILLIAM M. Oil Inspector, in Charge of Lubrication, American Sheet and Tin Plate Company, Sheridanville, Allegheny County, Pa.

1902. DE ARMOND, W. C. President, Protectus Company, 1103 North American Building, Philadelphia, Pa.

1904. DEWEESE, CORNELIUS. Chemist and Bacteriologist, Doctor of Medicine, Government Hospital for the Insane, Washington, D. C.

1904. DE WYRALL, CYRIL. Superintendent of Painting, Interborough Rapid Transit Company, New York City. *For Mail*, Ridgefield Park, N. J.

ELECTED.

1899. Deans, John Sterling. Chief Engineer, Phœnix Bridge Company, Phœnixville, Pa.

1904. Department of Engineering, Tufts College. Gardner C. Anthony, Dean, Tufts College, Mass.

1902. Derleth, Charles, Jr. Professor of Structural Engineering, University of California, Berkeley, Cal.

1904. Detroit Graphite Manufacturing Company. F. W. Davis, Jr., Second Vice-President, 141 Broadway, New York, N. Y.

1903. Deverell, H. F. Secretary, Otis Steel Company, Cleveland, O.

1903. Diederichs, H. Assistant Professor of Experimental Engineering, Cornell University, 913 North Aurora Street, Ithaca, N. Y.

1903. Diller, H. E. Chief Chemist, Western Electric Company, Chicago, Ill.

1903. Dimmick, J. K. 1049 Drexel Building, Philadelphia, Pa.

1904. Dinan, Edward. Chemist, Edison Portland Cement Company, 230 East Third Street, South Bethlehem, Pa.

1902. Dixon Crucible Company, Joseph. Malcolm McNaughton, Superintendent, Paint and Lubricating Department, Jersey City, N. J.

1903. *Dixon, R. M. Vice-President, The Safety Car Heating and Lighting Company, 160 Broadway, New York, N. Y.

1901. Doble, William A. Mechanical Engineer; President, Abner Doble Company, 200 Fremont Street, San Francisco, Cal.

1904. Dominion Bridge Company. Phelps Johnson, Manager, Montreal, Canada.

1898. Dow, A. W. Inspector of Asphalts and Cements, District of Columbia, Washington, D. C.

1903. Drake, C. F. Western Manager, Crowell, Dickman and Kenyon, Inspecting Engineers, 1120 Rookery Building, Chicago, Ill.

1903. Drummond, M. J. President, Glamorgan Pipe and Foundry Company, 192 Broadway, New York, N. Y.

1904. Dubbs, J. A. President, Globe Asphalt Company, 405 Bakewell Building, Pittsburg, Pa.

1902. Du Comb, W. C., Jr. Mechanical Engineer; Engineer of Tests, 1424 North Ninth Street, Philadelphia, Pa.

1896. *Dudley, Charles B. (*President*). Chemist, Pennsylvania Railroad, Altoona, Pa.

ELECTED.

1902. Dudley, P. H. Consulting Engineer, 80 Pine Street, New York, N. Y.

1901. Dufour, F. O. Assistant Professor of Civil Engineering, University of Vermont. *For Mail*, 28 Brooks Avenue, Burlington, Vt.

1902. Dumary, L. Henry. President, The Helderberg Cement Company, 38 State Street, Albany, N. Y.

1902. Dunbar, W. O. Assistant Engineer, Pennsylvania Railroad Testing Department, Altoona, Pa.

1904. Duncklee, John B. Civil and Consulting Engineer, 170 Broadway, New York, N. Y.

1904. Dunn, W. R. Superintendent, Vulcanite Portland Cement Company, Phillipsburg, N. J.

1904. Duryee, E. Cement Expert, U. S. Reclamation Service, Roosevelt, Ariz.

1904. Dwight, Theodore. Electrical Engineer, Post Office Box 223, New York, N. Y.

1902. Easby, M. Ward. Consulting Engineer, 909 Crozer Building, Philadelphia, Pa.

1902. Edwards, Warrick R. Assistant to Engineer of Bridges and Buildings, Baltimore and Ohio Railroad, Mount Royal Station, Baltimore, Md.

1904. Eidlitz, Otto M. Civil Engineer, 489 Fifth Avenue, New York, N. Y.

1903. Eldridge, G. F. B. Nicoll and Company, 59 Wall Street, New York, N. Y.

1896. Ely, Theodore N. Chief of Motive Power, Pennsylvania Railroad, Broad Street Station, Philadelphia, Pa.

1898. Engineering Record. 114 Liberty Street, New York, N. Y.

1903. Erlandsen, Oscar. Assistant Engineer, Department of Bridges, 32 Sutton Place, New York, N. Y.

1903. Esterline, J. Walter. Assistant Professor of Electrical Engineering, Purdue University, Lafayette, Ind.

1904. Evans, S. M. Manager New York Office, Picher Lead Company, 100 William Street, New York, N. Y.

1904. Ewen, John M. Vice-President, Thompson-Starrett Company, 1402 Railway Exchange, Chicago, Ill.

1904. Fackenthal, Jr., B. F. President, Thomas Iron Company, Easton, Pa.

ELECTED.

1903. Faculty Applied Science, McGill University. Henry T. Bovey, Dean, Montreal, Can.

1900. Fahrig, Ernst. Chief of Laboratories, Philadelphia Commercial Museums, Philadelphia, Pa.

1902. Falkenau, A. President, Falkenau-Sinclair Machine Company, Testing Machines, 109 North Twenty-second Street, Philadelphia, Pa.

1902. Farrel Foundry and Machine Company. Herbert E. Field, Metallurgist, Ansonia, Conn.

1902. Fay, Henry. Assistant Professor Analytical Chemistry and Metallography, Massachusetts Institute of Technology, Boston, Mass.

1904. Fenkell, Neal C. Civil Engineering Department of Water Works, Detroit, Mich.

1903. Fenner, L. M. Chemist, New York Air Brake Company, 10 Boyd Street, Watertown, N. Y.

1903. Fitzgerald, Francis A. J. Chemical Engineer, P. O. Box 118, Niagara Falls, N. Y.

1899. Flagg, Stanley G., Jr. Stanley G. Flagg and Company, Nineteenth Street and Pennsylvania Avenue, Philadelphia, Pa.

1904. Fleming, H. S. Editor, Iron and Steel Department, *Mining Magazine*, No. 1 Broadway, New York, N. Y.

1903. Fletcher, Austin B. Secretary, Massachusetts Highway Commission, 20 Pemberton Square, Boston, Mass.

1904. Fogarty, W. J. Superintendent, The Magnetite Foundry Company, St. Louis, Mo.

1904. Ford, Allen P. Metallurgist, Crane Company, 52 Judd Street, Chicago, Ill.

1901. Forrest, C. N. Chief Chemist, New York Testing Laboratory, Long Island City, N. Y.

1903. Forsyth, William. Mechanical Engineer, *Railway Age*, Chicago, Ill.

1904. Foster, W. C. Vice-President and General Manager, Glamorgan Pipe and Foundry Company, Lynchburg, Va.

1898. Franklin Institute. William H. Wahl, Secretary, 15 South Seventh Street, Philadelphia, Pa.

1903. French, James B. Bridge Engineer. The Long Island Railroad Company, 5 Hanson Place, Brooklyn, N. Y.

1903. French, Lester G. Editor, *Machinery*, 66 Broadway, New York, N. Y.

ELECTED.

1904. FROEHLING AND ROBERTSON. Analytical Chemists, Chemical and Mining Engineers, 17 South Twelfth Street, Richmond, Va.

1903. FULLER, ALMON H. Professor of Civil Engineering, Washington University, University Station, Seattle, Wash.

1904. FULLER, WM. B. Consulting Civil Engineer, 170 Broadway, New York, N. Y.

1903. GALBRAITH, J. Principal, School of Practical Science, Toronto, Can.

1902. GERSTELL, A. F. Vice-President and General Manager, Alpha Portland Cement Company, Alpha, N. J.

1902. GIBBS, A. W. General Superintendent of Motive Power, Pennsylvania Railroad, Altoona, Pa.

1902. GIBBS, GEORGE. First Vice-President, Westinghouse, Church, Kerr and Company, 10 Bridge Street, New York, N. Y.

1903. GILMOUR, EDWARD B. Superintendent, The Cook Heater Company, 301 North Perry Avenue, Peoria, Ill.

1904. GIROUX, GUSTAVE. Inspector of Materials, Canadian Pacific Railway Company, 5 Craig Street, Montreal, P. Q., Canada.

1904. GLASGOW IRON COMPANY. C. B. Shoemaker, President, 603-608 Harrison Building, Philadelphia, Pa.

1904. GODWIN, W. S. General Manager, American Block Press Company, 404 Temple Bar Building, Brooklyn, N. Y.

1904. GOODMAN, CARLTON M. Chemist, Virginia Portland Cement Company, Fordwick, Va.

1904. *GOODNOW, C. A. General Manager, Chicago and Alton Railroad, Chicago, Ill.

1904. GOODSPEED, G. M. Metallurgist, National Tube Company, McKeesport, Pa.

1904. GOODWIN, H. S. Bridge Inspector, 201 North Owen Avenue, Lansdowne, Pa.

1896. GOSS, WILLIAM F. M. Dean of the Schools of Engineering, Purdue University, Lafayette, Ind.

1904. GOWEN, CHARLES S. Engineer, New Croton Dam, Ossining, N. Y.

1903. GRANTHAM, HERBERT T. Chief Engineer, Belmont Iron Works, 1622 Real Estate Trust Building, Philadelphia, Pa.

ELECTED.

1899. Graves, Edwin D. Chief Engineer, Connecticut River Bridge and Highway District, 650 Main Street, Hartford, Conn.

1903. Gray, John Lathrop. Assistant Superintendent, Tidewater Oil Company, East Twenty-second Street, Bayonne, N. J.

1896. Gray, Thomas. Professor Dynamic Engineering, Rose Polytechnic Institute, Terre Haute, Ind.

1904. Green, Morris M. Professor of Mechanical Engineering, Colorado State University, Boulder, Col.

1904. Greenman Russell S. Assistant Engineer, State Engineer's Department, Albany, N. Y.

1902. Greiner, J. E. Engineer of Bridges and Buildings, Baltimore and Ohio Railroad, Mt. Royal Station, Baltimore, Md.

1904. Gregory, W. B. Assistant Professor of Experimental Engineering, Tulane University, New Orleans, La.

1904. Guppy, Benj. C. Bridge Engineer, Maine Central Railroad, 238 St. John Street, Portland, Maine.

1901. Hagar, Edward M. Manager, Cement Department, Illinois Steel Company, 1060 The Rookery, Chicago, Ill.

1903. Hallett, Nelson A. Cement Inspector, 1 Ashburton Place, Boston, Mass.

1904. *Hammond, R. R. Second Vice-President, St. Louis and San Francisco Railroad, St. Louis, Mo.

1903. Hancock, E. L. Instructor Applied Mechanics, Purdue University, Lafayette, Ind.

1904. *Harahan, J. T. Second Vice-President, Illinois Central Railroad, Chicago, Ill.

1904. Harding, James J. Assistant Engineer, Chicago, Milwaukee and St. Paul Railway, 1232 Railway Exchange Building, Chicago, Ill.

1902. Harding, W. H. President, Bonneville Portland Cement Company, 2029 Land Title Building, Philadelphia, Pa.

1903. Hargrove, Julian O. Assistant Inspector of Asphalt and Cement, 1603 O Street, N. W., Washington, D. C.

1902. Harriman, N. F. Chemist and Engineer of Tests, Union Pacific Railroad, Omaha, Neb.

1904. Hartley, Henry J. Superintendent, Boiler Department, William Cramp and Sons, 1624 Oxford Street, Philadelphia.

ELECTED.

1898. HARTRANFT CEMENT COMPANY, WILLIAM G. Sole Selling Agent for Old Dominion and Phœnix Portland Cement, Real Estate Trust Building, Philadelphia, Pa.

1898. HATT, WILLIAM K. Professor of Applied Mechanics, Purdue University, Lafayette, Ind.

1904. HAUGHTON, FRANK A. General Inspector, American Locomotive Company, Schenectady, N. Y.

1904. HAWXHURST, ROBERT. Chief Engineer, Kohala and Hilo Railway Company, Hilo, Territory of Hawaii.

1904. HAYES, HAMMOND V. Engineer, American Telephone and Telegraph Company, 125 Milk Street, Boston, Mass.

1903. HEARNE, W. W. 1625 Real Estate Trust Building, Philadelphia, Pa.

1904. HEIDENREICH, E. LEE. Consulting Engineer, 721 The Rookery, Chicago, Ill.

1904. HELWIG, ALFRED. Testing Engineer, Brooklyn Heights Railroad Company, Central Power Station, Second Street and Third Avenue, Brooklyn, N. Y.

1904. HEMSTREET, GEORGE P. Superintendent, Hastings Pavement Company, Hastings-on-Hudson, N. Y.

1903. HENSHAW, JOHN O. Member, N. S. Bartlett and Company, 126 State Street, Boston, Mass.

1904. HERING, RUDOLPH. Hydraulic and Sanitary Engineer, 170 Broadway, New York, N. Y.

1902. HILDRETH, P. S. Consulting and Inspecting Engineer, 32 Broadway, New York, N. Y.

1904. HILL, CHARLES S. Associate Editor, *The Engineering News*, 220 Broadway, New York, N. Y.

1903. HILTNER, R. S. Assistant Chemist, Supervising Architect's Office, Treasury Department, Washington, D. C.

1904. HOFF, OLAF. Engineer of Structures, New York Central and Hudson River Railroad, Grand Central Station, New York, N. Y.

1902. HOFMAN, H. O. Professor of Metallurgy, Massachusetts Institute of Technology, Boston, Mass.

1903. HOLMES, JOSEPH A. State Geologist of North Carolina, Chapel Hill, N. C.

1904. HOPTON, W. E. Assistant Purchasing Engineer, Solvay Process Company, Syracuse, N. Y.

1904. HOW, R. W. Chief Inspector, Bridge Engineer's Office, Long Island Railroad Company, 5 Hanson Place, Brooklyn, N. Y.

ELECTED.

1903. Howard, L. E. Superintendent, Simonds Manufacturing Company, Seventeenth Street and Western Avenue, Chicago, Ill.

1896. Howe, Henry M. *(Past-President)*. Professor Metallurgy, Columbia University, 27 West Seventy-third Street, New York, N. Y.

1903. Hoy, John F. Chemist, Pennsylvania Car-Wheel Company, Preble Avenue, Allegheny, Pa.

1904. Hubbell, C. A. President, R. Almond Manufacturing Company, Brooklyn, N. Y.

1904. Huber, Frederick W. Engineer of Tests, U. S. Geological Survey, Berkeley, Cal.

1904. Hull, Geo. H. President, American Pig Iron Storage Warrant Company, 44 Wall Street, New York, N. Y.

1904. Hume, A. P. Engineer of Tests, American Bridge Company, Pencoyd, Pa.

1896. Humphrey, Richard L. Consulting Engineer and Chemist, 1001 Harrison Building, Philadelphia, Pa.

1903. Hunnings, S. V. Engineer of Tests, American Locomotive Company, Pittsburg, Pa.

1903. Hunt, Loren E. Timber Inspecting Expert, U. S. Bureau of Forestry, University of California, Berkeley, Cal.

1899. Hunt, Robert W., Company. Inspecting and Testing Engineers, 1121 The Rookery, Chicago, Ill.

1903. Hunter, Joseph W. Engineer and Surveyor, State Highway Commissioner, Harrisburg, Pa.

1899. Huston, Charles L. Vice-President, Lukens Iron and Steel Company, Coatesville, Pa.

1904. Hutchinson, George W. Engineer of Tests, American Locomotive Company, Richmond Works, Richmond, Va.

1903. Hyde, Charles G. Assistant Engineer in Charge of Filters, Board of Public Works, Harrisburg, Pa.

1900. *Illinois Steel Company. P. E. Carhart, Inspecting Engineer, Rookery Building, Chicago, Ill.

1903. Insurance Engineering. Franklin Webster, Editor, 120 Liberty Street, New York City, N. Y.

1902. International Acheson Graphite Company. Manufacturers of Graphite and Graphite Articles, Niagara Falls, N. Y.

1904. International Harvester Company. F. A. Flather, Superintendent, McCormick Division, Blue Island and Western Avenues, Chicago, Ill.

ELECTED.

1902. IRON TRADE REVIEW, THE. A. I. Findley, Editor, Cleveland, O.

1896. JARECKI, ALEXANDER. Superintendent, Jarecki Manufacturing Company, Limited, Erie, Pa.

1904. JENKINS, JOEL. President, Round Top Cement Company, 43 Lincoln Street, Montclair, N. J.

1897. JENKINS, JOHN. General Manager, Milton Iron Company, Milton, Pa.

1904. JENNINGS, ARTHUR S. Editor, *The Decorator*, 365 Birkbeck Bank Chambers, High Holborn, London, W. C., England.

1900. JEWETT, J. Y. Cement Inspector, Reclamation Service, U. S. Geological Survey, Denver, Col.

1900. JOB, ROBERT. Chemist, Philadelphia and Reading Railway, Reading, Pa.

1903. JOHNSON, ALBERT L. Chief Engineer, Expanded Metal Fireproofing Company, 606 Century Building, St. Louis, Mo.

1903. JOHNSON, ARTHUR N. Civil Engineer; Highway Engineer, Maryland Geological Survey, Baltimore, Md.

1903. JOHNSON, CHARLES. Testing Department, American Locomotive Company, Schenectady, N. Y.

1904. JOHNSON, CHARLES C. Cement Inspector, Boston Transit Commission, 15 Beaver Street, Boston, Mass. *For Mail*, 141 High Street, Danvers, Mass.

1904. JOHNSON, J. S. A. In charge of Testing Laboratory, Virginia Polytechnic Institute, Blacksburg, Va.

1904. JOHNSON, LEWIS J. Assistant Professor of Civil Engineering, Harvard University, 309 Pierce Hall, Cambridge, Mass.

1900. JOHNSON, WALLACE C. Consulting Engineer, Niagara Falls, N. Y.

1904. JOHNSON, W. MARTIN. Vice-President, The Schoen Steel Wheel Company, 1119 Frick Building, Pittsburg, Pa.

1902. *JONES AND LAUGHLINS, LIMITED. Steel Manufacturers; Willis L. King, Vice-Chairman, Pittsburg, Pa.

1903. JORDAN, WILLIAM, JR. Box 33, Southern Pines, Moore County, N. C.

1904. KAHN, MORITZ. Resident Representative, Trussed Concrete Steel Company, 160 Fifth Avenue, New York, N. Y.

ELECTED.

1904. Kasson, Henry R. District Manager, Barber Asphalt Paving Company, 1236 Stock Exchange Building, Chicago, Ill.

1904. Kay, Edgar B. Professor of Engineering, University of Alabama, University Post Office, Ala.

1903. Keay, H. O. Chief Draughtsman, Motive Power Department, Boston and Maine Railroad, Boston, Mass.

1896. Keep, William J. Superintendent, Michigan Stove Company, 753 Jefferson Avenue, Detroit, Mich.

1898. Kemp, James F. Professor of Geology, School of Mines, Columbia University, New York, N. Y.

1899. Kennedy, Frank G., Jr. Superintendent, Logan Iron and Steel Company, Burnham, Mifflin County, Pa.

1904. Kennedy, Jeremiah J. Consulting Engineer, 52 Broadway, New York, N. Y.

1899. Kennedy, Julian. Consulting Engineer, Latrobe Steel Company, Pittsburg, Pa.

1904. Kenney, E. F. Engineer of Tests, Pennsylvania Railroad Company, Broad Street Station, Philadelphia, Pa.

1902. Kennicott, Cass L. General Manager, Kennicott Water Softener Company, 3567 Butler Street, Chicago, Ill.

1902. Kent, William. Professor of Mechanical Engineering, and Dean of the L. C. Smith College of Applied Science, Syracuse University, Syracuse, N. Y.

1904. Kenyon, Clarence A. President, Hoosier Construction Company and Granite Bituminous Paving Company, Indianapolis, Ind.

1904. Kenyon, E. H. Inspecting Engineer, 421 Wood Street, Pittsburg, Pa.

1903. Kiesel, W. F., Jr. Assistant Mechanical Engineer, Pennsylvania Railroad, Altoona, Pa.

1899. King, Willis L. Vice-Chairman, Jones and Laughlins, Limited, Pittsburg, Pa.

1899. Kinkead, J. A. Engineer of Tests, American Locomotive Company, Schenectady, N. Y.

1902. Kirchhoff, C. Editor, *The Iron Age*, 232 William Street, New York, N. Y.

1903. Kirchner, Paul A. Bridge Engineer, Chesapeake and Ohio Railway, Richmond, Va.

1903. Kittredge, H. G. Secretary, The Kay and Ess Company, Dayton, O.

1904. Knight, Frank B. Engineer, Lidgerwood Manufacturing Company, 96 Liberty Street, New York, N. Y.

ELECTED.

1903. KNIGHTON, J. A. Assistant Engineer, Bridge Department, Park Row Building, New York, N. Y.

1904. KNOWLES, MORRIS. Chief Engineer, Bureau of Filtration, Pittsburg, Pa.

1903. KOHR, D. A. Chemist, Lowe Brothers, Dayton, O.

1896. KREUZPOINTNER, PAUL. Pennsylvania Railroad, Altoona, Pa.

1904. KRUPP COMPANY, Fried.; Emil Ehrensberger, Director, Essen, Germany.

1904. KUMMER, FREDERIC A. General Manager, United States Wood Preserving Company, 29 Broadway, New York, N. Y.

1903. LA CHICOTTE, H. A. Engineer in Charge, Manhattan Bridge (No. 3) and Blackwell's Island Bridge (No. 4), Park Row Building, New York, N. Y.

1903. LANE, HENRY M. Editor, *The Foundry*, Rose Building, Cleveland, O.

1899. LANZA, GAETANO. Professor Theoretical and Applied Mechanics, in charge Mechanical Engineering Department, Massachusetts Institute of Technology, Boston, Mass.

1904. LARNED, E. S. Manager, United Building Materials Company, 101 Milk Street, Boston, Mass.

1903. LARSSON, C. G. E. Assistant Chief Engineer, American Bridge Company, Ambridge, Pa.

1898. *LATROBE STEEL COMPANY. Marriott C. Smyth, President, 1200 Girard Building, Philadelphia, Pa.

1901. LAWRENCE, WILLIAM H. Assistant Professor of Architecture, Massachusetts Institute of Technology, Boston, Mass.

1903. LAYMAN, W. A. General Manager, Wagner Electrical Manufacturing Company, 2017 Locust Street, St. Louis, Mo.

1904. LEIGHTON, MARSHALL O. Chief, Division of Hydro-Economics, United States Geological Survey, Washington, D. C.

1904. LEMEN, W. W. Engineer of Tests, Norfolk and Western Railway, Roanoke, Va.

1903. LEMOINE, L. R. Resident Manager, United States Cast-Iron Pipe and Foundry Company, Land Title Building, Philadelphia, Pa.

1898. *LESLEY, R. W. (*Vice-President*). President, American Cement Company, Pennsylvania Building, Philadelphia, Pa.

ELECTED.

1903. Lewis, Frederick H. Manager, Virginia Portland Cement Company, Fordwick, Va.

1902. Lewis, George T. Secretary and Treasurer, Monongahela Iron and Steel Company, Box 215, Pittsburg, Pa.

1904. Lewis, Nelson P. Chief Engineer, Board of Estimate and Apportionment, City Hall, New York, N. Y.

1904. Lidgerwood, John H., Jr. Engineer, Lidgerwood Manufacturing Company, 96 Liberty Street, New York, N. Y.

1896. Lindenthal, Gustav. Consulting Engineer, 45 Cedar Street, New York, N. Y.

1902. Linton, Harvey. City Engineer, Altoona, Pa.

1903. Little and Walker, Chemical Experts and Engineers, 93 Broad Street, Boston, Mass.

1903. Lobdell, W. W. President, Lobdell Car-Wheel Company, Wilmington, Del.

1902. Lober, J. B. Vice-President, Vulcanite Portland Cement Company, Land Title Building, Philadelphia, Pa.

1904. Lober, W. H. Inspector General, Barber Asphalt Paving Company, Land Title Building, Philadelphia, Pa.

1902. Lockard, Charles A. Manager Empire Portland Cement Company, Warners, N. Y.

1904. Long, R. A. President and General Manager, The Long-Bell Lumber Company, Keith and Perry Building, Kansas City, Mo.

1904. Long, William. Engineer of Tests, Bureau of Engraving and Printing, 2133 K Street, N. Washington, D. C.

1904. Loomis, Henry M. Chemist, Box 311, Norristown, Pa.

1904. Lord, E. C. E. Petographer, U. S. Department of Agriculture, Washington, D. C.

1903. Lordly, Henry Robertson. Engineer in Charge, Lachine Canal, Royal Insurance Building, Montreal, Canada.

1904. Loudenbeck, H. C. Chemist and Metallurgist for Westinghouse Air Brake Company, Wilmerding, Pa.

1903. Loudon, Arch. M. Foundryman, 460 Spaulding Street, Elmira, N. Y.

1902. Lovell, Earl B. Adjunct Professor of Civil Engineering, Columbia University, 235 West One Hundred and Second Street, New York, N. Y.

1899. Lowe Brothers. Paint and Color Makers; Houston Lowe, Vice-President, Dayton, O.

ELECTED.

1900. LOWETH, CHARLES F. Engineer and Superintendent of Bridges and Buildings, Chicago, Milwaukee and St. Paul Railway, 1232 Railway Exchange, Chicago, Ill.

1904. LUDLOW, S. H. Chemist, National Portland Cement Company, Durham, Ontario, Canada.

1902. LUKENS IRON AND STEEL COMPANY. Charles L. Huston, Vice-President, Coatesville, Pa.

1898. LUNDTEIGEN, ANDREAS. Chemist, Union City, Mich.

1902. LYNCH, T. D. Engineer of Material Tests, Westinghouse Electric and Manufacturing Company, East Pittsburg, Pa.

1904. MACDONALD, JAMES H. Landscape Architect, State Highway Commission, Capitol, Hartford, Conn.

1902. MACPHERRAN, R. S. Chemist, Allis-Chalmers Company, Milwaukee, Wis.

1896. MCCAULEY, H. K. Secretary and Treasurer, Altoona Iron Company, Altoona, Pa.

1903. MCCREADY, ERNEST B. Cement Tester, Rapid Transit Railroad Commission, City of New York, 414 Turner Street, Allentown, Pa.

1896. MCKENNA, CHARLES F. Chemist, 221 Pearl Street, New York, N. Y.

1904. MCLEAN, E. Foreman, Wheel Foundry, Pennsylvania Railroad, Altoona, Pa.

1902. *MCLEOD, JOHN (*Member of Executive Committee*). Assistant to President, Carnegie Steel Company, Pittsburg, Pa.

1904. MCNAUGHER, D. W. Civil Engineer, Monongahela Bank Building, Pittsburg, Pa.

1903. MCQUEEN, J. W. Secretary, Sloss-Sheffield Iron and Steel Company, Birmingham, Ala.

1904. MACK, J. LATHROP. Chemist, Penn-Allen Portland Cement Company, Nazareth, Pa.

1895. MACLAY, WILLIAM W. President, Glens Falls Portland Cement Company, Glens Falls, N. Y.

1904. MAHON, R. W. Chemist, New York Central and Hudson River Railroad, West Albany, N. Y.

1902. MAJOR, CHARLES. President, A. and P. Roberts Company; Manager, Pencoyd Iron Works, Pencoyd, Pa.

1898. MARBURG, EDGAR (*Secretary-Treasurer*). Professor of Civil Engineering, University of Pennsylvania, Philadelphia, Pa.

1903. MARTIN, HENRY G. Metallurgist, Lukens Iron and Steel Company, P. O. Box 478, Coatesville, Pa.

ELECTED.

1902. Martin, Simon S. Superintendent, Maryland Steel Company, Sparrows Point, Md.

1903. Masters, J. B. Inspecting Engineer, Pittsburg Representative of Hildreth and Company, 506 North St. Clair Street, Pittsburg, Pa.

1902. Matcham, Charles A. Manager, Lehigh Portland Cement Company, Allentown, Pa.

1903. Mathews, John A. Metallurgist, Experimental Department, Crucible Steel Company of America, Syracuse, N. Y.

1904. Maurer, E. R. Professor of Mechanics, University of Wisconsin, Madison, Wis.

1904. Mead, Charles Adriance. Principal Assistant to Boller and Hodge, Engineers, New York, N. Y., 165 Wildwood Avenue, Upper Montclair, N. J.

1899. Meade Richard K. Chemist, Dexter Portland Cement Company, Nazareth, Pa.

1902. Meier, E. D. President and Chief Engineer, Herne Safety Boiler Company, 11 Broadway, New York, N. Y.

1895. Merriman, Mansfield (*Past-President*). Professor of Civil Engineering, Lehigh University, South Bethlehem, Pa.

1903. Metcalf, William. Braeburn Steel Company, Braeburn, Pa.

1904. Millar, W. G. A. Purchasing Agent, American Bridge Company, 30 Orchard Avenue, Bellevue, Pa.

1903. Miller, John S., Jr. Assistant Chemist, Supervising Architect's Office, Treasury Department, Washington, D. C.

1903. Miller, Rudolph P. Chief Engineer, Bureau of Buildings, 141 East Fortieth Street, New York, N. Y.

1900. Mills, Charles M. Principal Assistant Engineer, Subway and Elevated Railroad Construction, Rapid Transit Company, Philadelphia, Pa.

1903. Mitchell, Arthur M. Secretary, The Eureka Chemical Company, 5 Howard Street, Newark, N. J.

1904. Mitchell, A. S. Analytical Chemist, 220 Greenbush Street, Milwaukee, Wis.

1903. *Mitchell, Joseph. With John Williams Bronze and Iron Works, 556 West Twenty-seventh Street, New York City, N. Y.

1901. Mitchell, William H. 519 Arch Street, Philadelphia, Pa.

1904. Mix, Charles Dorf. Steel Merchant, 102 Purchase Street, Boston, Mass.

ELECTED.

1903. MOISSEFF, LEON S. Assistant Engineer to Commissioner of Bridges, 13 Park Row, New York City, N. Y.

1896. MOLDENKE, RICHARD. Metallurgist, Consulting Engineer, Watchung, N. J.

1903. MOORE, HERBERT F. Instructor in Testing Laboratory, University of Wisconsin, 919 University Avenue, Madison, Wis.

1902. MOORE, WILLIAM HARLEY. Engineer of Bridges, New York, New Haven and Hartford Railroad, New Haven, Conn.

1904. MOSELEY, ALEX. W. Professor of Applied Mechanics, Lewis Institute, Chicago, Ill.

1899. MUESER, WILLIAM. Civil Engineer; Member, Concrete Steel Engineering Company, 13–21 Park Row Building, New York, N. Y.

1903. MUNROE, CHARLES E. Columbian University, Washington, D. C.

1904. MUNSELL, A. W. Cement Inspector, Baltimore and Ohio Railroad, Twenty-first and Water Streets, Wheeling, W. Va.

1899. MUTUAL BOILER INSURANCE COMPANY. 31 Milk Street, Boston, Mass.

1904. NAEGELEY, JOHN C. Engineer and Architect, 82 Montague Street, Brooklyn, N. Y.

1900. NATIONAL TUBE COMPANY. Frank N. Speller, Frick Building, Pittsburg, Pa.

1896. NEALE, JAMES. Secretary, Wayne Iron and Steel Works, Pittsburg, Pa.

1902. NEFF, F. H. Professor of Civil Engineering, Case School of Applied Science, Cleveland, O.

1904. NEILSON, GEORGE HARRISON. General Manager, Braeburn Steel Company, Braeburn, Pa.

1904. NELSON, E. D. Engineer of Tests, Pennsylvania Railroad Company, Altoona, Pa.

1902. NEW YORK AIR BRAKE COMPANY, THE. R. C. Augur, Mechanical Engineer, Watertown, N. Y.

1904. NEW YORK FIRE INSURANCE EXCHANGE. Henry Hess, Manager, 32 Nassau Street, New York, N. Y.

1898. NEWBERRY, SPENCER B. Manager, Sandusky Portland Cement Company, Sandusky, O.

1902. NORRIS, GEORGE L. Chemist, Standard Steel Works, Burnham, Pa.

1903. NORTON, C. L. Assistant Professor of Heat Measurement, Massachusetts Institute of Technology, Boston, Mass.

ELECTED.

1904. Norton, F. Lee. General Manager, J. I. Case Threshing Machine Company, Racine, Wis.

1898. Olsen, Tinius. Tinius Olsen and Company. Testing Machines, 500 North Twelfth Street, Philadelphia, Pa.

1902. Onderdonk, J. R. Engineer of Tests, Baltimore and Ohio Railroad, Mt. Clare, Baltimore, Md.

1903. *Orford Copper Company. 43 Exchange Place, New York, N. Y.

1902. Orton, Edward, Jr. Dean, College of Engineering, Ohio State University, and State Geologist of Ohio, Columbus, O.

1898. Osborn Engineering Company, The. Frank C. Osborn, Cleveland, O.

1903. Ostrom, John N. Bridge Engineer, 1518 Farmers' Bank Building, Pittsburg, Pa.

1904. Otis, Spencer. Mechanical Engineer, 1707 Railway Exchange Building, Chicago, Ill.

1902. Outerbridge, Alex. E., Jr. Chemist and Metallurgist, 1600 Hamilton Street, Philadelphia, Pa.

1904. Owen, James. Civil Engineer, 196 Market Street, Newark, N. J.

1903. Page, Logan Waller. Chief of Road Material Laboratory, United States Department of Agriculture, Washington, D. C.

1903. Park, Louis L. Chief Draughtsman, Rogers Locomotive Works, Paterson, N. J.

1902. Patterson-Sargent Company. Benjamin Patterson, President, Cleveland, O.

1904. Pearson, Henry. Vice-President and General Manager Wason Manufacturing Company, Brightwood, Mass.

1896. Pease, F. N. Assistant Chemist, Pennsylvania Railroad, Altoona, Pa.

1903. Peckham, S. F. Chemist to the Commissioners of Accounts, New York City, Room 104, 280 Broadway, New York, N. Y.

1903. Peckitt, Leonard. President, Empire Steel and Iron Company, Catasauqua, Pa.

1904. Peebles, John. Factory Superintendent, J. I. Case Threshing Machine Company, 712 Lake Avenue, Racine, Wis.

ELECTED.

1902. *Pennsylvania Steel Company, The. H. H. Campbell, Superintendent and General Manager, Steelton, Pa.

1904. Perley, George E. Cement Expert, Department of Public Works, Ottawa, Canada.

1903. Phillips, William Battle. Mining Engineer and Metallurgist; Director, University of Texas Mineral Survey, Austin, Tex.

1903. Pinchot, Gifford. Forester, United States Department of Agriculture, Washington, D. C.

1904. Pittsburg Forge and Iron Company. F. E. Richardson, Secretary, Pittsburg, Pa.

1902. *Polk, W. A. Sales Agent, The Patterson-Sargent Company, 42 Hudson Street, New York, N. Y.

1904. Pomeroy, Lewis R. Special Representative, Railway Department, General Electric Company, 44 Broad Street, New York, N. Y.

1898. Porter, James Madison. Professor of Civil Engineering, Lafayette College, Easton, Pa.

1903. Powell, H. S. Sanitary Engineer, 149 Broadway, New York, N. Y.

1904. Powell, J. E. Chief Mechanical and Electrical Engineer, Office of Supervising Architect, Treasury Department, Washington, D. C.

1903. Powers, W. A. Chief Chemist, Atchison, Topeka and Santa Fé Railroad, Topeka, Kan.

1904. Prentiss, George N. Chemist, Chicago, Milwaukee and St. Paul Railway, 2910 Clybourn Street, Milwaukee, Wis.

1904. Preston, S. R. Superintendent, Virginia Portland Cement Company, Fordwick, Augusta County, Va.

1903. Price, Morton Moore. Civil Engineer, Babcock and Wilcox Company, Bayonne, N. J.

1904 Prince, J. W. Superintendent, Great Northern Portland Cement Company, Marlborough, Mich.

1904. Purdon, C. D. Engineer, Maintenance of Way, Frisco System, Frisco Building, St. Louis, Mo.

1904. Quimby, Charles H. Assistant Engineer, Yards and Buildings, American Bridge Company, 115 Rochelle Avenue, Wissahickon, Philadelphia, Pa.

1903. Quimby, H. H. Assistant Engineer of Bridges, Bureau of Surveys, 863 North Twenty-third Street, Philadelphia, Pa.

ELECTED.

1898. Railroad Gazette. W. H. Boardman, Editor, 83 Fulton Street, New York, N. Y.

1902. Railway and Engineering Review. W. M. Camp, Editor, 1305 Manhattan Building, Chicago, Ill.

1904. Ramage, J. C. Superintendent of Tests, Southern Railway Company, Alexandria, Va.

1904. Ramsay, H. Martyn. General Inspector, Pennsylvania Railroad Company, Altoona, Pa.

1896. Randolph, Lingan S. Professor of Mechanical Engineering, Virginia Polytechnic Institute, Blacksburg, Va.

1902. Reading Iron Company. David Thomas, Superintendent, Montour Rolling Mills, Danville, Pa.

1904. Reeve, C. S. Chemist, Philadelphia Municipal Testing Laboratories, 318 City Hall, Philadelphia, Pa.

1902. Reid, David. General Foreman, Foundry Department, Canadian Westinghouse Company, Limited, 253 Wentworth Street, Hamilton, Canada.

1898. Rice, Francis S. Structural Engineer, Aspinwall, Pa.

1900. Richards, Joseph T. Chief Engineer, Maintenance of Way, Pennsylvania Railroad, Broad Street Station, Philadelphia, Pa.

1902. Richards, Joseph W. Assistant Professor of Metallurgy, Lehigh University, Bethlehem, Pa.

1902. Richards, Robert H. Professor of Mining Engineering and Metallurgy, Massachusetts Institute of Technology, Boston, Mass.

1904. Richards, W. D. Houghton and Richards, 150 Oliver Street, Boston, Mass.

1896. Richardson, Clifford. Asphalt Expert, New York Testing Laboratory, Long Island City, N. Y.

1903. Richardson, Willard D. Ceramic Engineer, Columbus, O.

1900. Richter, A. W. Assistant Professor of Experimental Engineering, University of Wisconsin, 428 Murray Street, Madison, Wis.

1902. Riegner, W. B. Engineer of Bridges, Philadelphia and Reading Railway, Reading Terminal, Philadelphia.

1898. Riehle, Frederick A. Riehlé Brothers Testing Machine Company, 1424 North Ninth Street, Philadelphia, Pa.

1904. Roberts, Alfred E. Analytical and Consulting Chemist and Metallurgist, Bull and Roberts, 100 Maiden Lane, New York, N. Y.

ELECTED.

1904. ROBERTSON, LESLIE S. Secretary of the Engineering Standards Committee, 28 Victoria Street, London, England.

1904. ROBINSON, A. F. Bridge Engineer, Atchison, Topeka and Santa Fé Railroad, 1000 Railway Exchange Building, Chicago, Ill.

1903. ROBINSON, JOHN C. Secretary and Treasurer, St. Louis Portland Cement Company, St. Louis, Mo.

1904. ROCK PRODUCTS. S. V. Peppel, Technical Editor, 431 West Main Street, Louisville, Ky.

1900. ROEBLING'S (JOHN A.) SONS COMPANY. J. H. Janeway, Jr., Mechanical Engineer, Trenton, N. J.

1904. ROEPPER, C. W. Metallurgical Engineer, Mount Airy Station, Philadelphia, Pa.

1903. ROYAL, JOSEPH. Inspecting Engineer, P. O. Box 174, Rutledge, Pa.

1904. RUTHENBURG, MARCUS. Electro-Metallurgical Engineer, Lockport, N. Y.

1898. SABIN, A. H. Chemist, 45 Broadway, New York, N. Y.

1902. SABIN, L. C. United States Assistant Engineer, Engineer Department, U. S. Army, Sault Ste. Marie, Mich.

1902. SAGUE, J. E. Vice-President, American Locomotive Company, 25 Broad Street, New York, N. Y.

1904. SALMON, FREDERICK W. Civil and Mechanical Engineer, 127 South Central Avenue, Burlington, Iowa.

1904. SAUNDERS, GEORGE C. Manager, Eastern District, The Osborn Engineering Company, 1122 Land Title Building, Philadelphia, Pa.

1902. SAUNDERS, WALTER M. Analytical and Consulting Chemist, 184 Whittier Avenue, Providence, R. I.

1896. SAUVEUR, ALBERT. Assistant Professor of Metallurgy, Harvard University; Manager, Boston Testing Laboratories, 446 Tremont Street, Boston, Mass.

1903. SCARBOROUGH, F. W. Engineer, Maintenance of Way, Chesapeake and Ohio Railway, 302 West Franklin Street, Richmond, Va.

1904. SCHADE, G. C. Vice-President and General Manager, Braddock Machine and Manufacturing Company, Braddock, Pa.

1898. SCHAFFER, HERBERT A. Chief Chemist, The Northampton and Quaker Portland Cement Company, 321 Spring Garden Street, Easton, Pa.

ELECTED.

1904. Schenk, Pierce D. Vice-President and Assistant General Manager, The Dayton Malleable Iron Company, Dayton, O.

1904. Schmitt, F. E. Associate Editor, *The Engineering News*, 220 Broadway, New York, N. Y.

1900. Schneider, Herman. Professor of Civil Engineering, University of Cincinnati, Cincinnati, O.

1903. Schroeder, C. M. Chemist, 221 Pearl Street, New York, N. Y.

1902. Schuerman, W. H. Dean of Engineering Department and Professor of Civil Engineering, Vanderbilt University, Nashville, Tenn.

1904. Scott, William F. Structural Engineer, Dunnville, Ontario, Can.

1902. Scott, W. G. Chemist, J. I. Case Threshing Machine Company, 1109 Park Avenue, Racine, Wis.

1898. Seaman, Harry J. Superintendent, Atlas Cement Company, Catasauqua, Pa.

1902. Seaman, Henry B. Civil Engineer, 40 Wall Street, New York, N. Y.

1904. Sellers and Company, William. William Sellers, President, 1600 Hamilton Street, Philadelphia, Pa.

1902. Shankland, E. C. and R. M. Civil Engineers, 1106 Rookery, Chicago, Ill.

1903. Sheaff, J. C. Manager, Patterson-Sargent Company, 42 Hudson Street, New York, N. Y.

1902. Shelby Steel Tube Company. J. H. Nicholson, Assistant to First Vice-President, The Frick Building, Pittsburg, Pa.

1903. Sherman, C. W. General Manager, Pennsylvania Malleable Company, Central Car Wheel Company, Frick Building, Pittsburg, Pa.

1904. Sherman, Herbert L. Analytical Chemist, 220 Devonshire Street, Boston, Mass.

1903. Sherrerd, Morris R. Engineer and Superintendent, Department of Water, City of Newark, 128 Halsey Street, Newark, N. J.

1902. Sherwin-Williams Company, The. Paint and Varnish Makers, E. C. Holton, Chemist in Chief, 100 Canal Street, Cleveland, O.

1899. Shimer, Porter W. Chemist and Metallurgist, Easton, Pa.

1902. Shuman, Jesse J. Chief Inspector, Testing Department, Jones and Laughlins, Limited, 837 Heberton Avenue, Pittsburg, Pa.

ELECTED.

1904. SIMMONS, WILLIAM H. Chief Chemist, Aetna Portland Cement Company, Fenton, Mich.

1904. SIMPSON BROTHERS CORPORATION. 166 Devonshire Street, Boston, Mass.

1903. SKINNER, C. E. Electrical Engineer, Westinghouse Electric Manufacturing Company, East Pittsburg, Pa.

1904. SKINNER, ORVILLE CAMPBELL. Superintendent, Open-Hearth Department, Standard Steel Works, P. O. Box 165, Burnham, Pa.

1903. SLOCUM, A. W. General Superintendent, Keystone Car Wheel Company, 5500 Irwin Ave., Pittsburg, Pa.

1902. SMITH, H. E. Chemist, The Lake Shore and Michigan Southern Railway Company, Collinwood, O.

1904. SNODGRASS, A. E. Concrete Engineer, 2318 Delaware Street, Indianapolis, Ind.

1902. SNOW, J. P. Bridge Engineer, Boston and Maine Railroad, Boston, Mass. *For Mail*, 58 Chandler Street, West Somerville, Mass.

1904. SOLVAY PROCESS COMPANY, THE. George B. Hartley, Chief Inspector, Syracuse, N. Y.

1904. SOMERVILLE, C. W. Computer in charge of Tests, Building Department, Washington, D. C.

1904. SOULE, R. H. Consulting Engineer, 20 West Thirty-fourth Street, New York, N. Y.

1903. SOUTHER, HENRY. Consulting Metallurgical Engineer, State Chemist, 440 Capitol Avenue, Hartford, Conn.

1904. SPACKMAN HENRY S., ENGINEERING COMPANY, 42 North Sixteenth Street, Philadelphia, Pa.

1902. SPANGLER, H. W. Professor of Mechanical Engineering, University of Pennsylvania, Philadelphia, Pa.

1901. SPERRY, W. L. Superintendent and Manager, The Cumberland Hydraulic Cement and Manufacturing Company, P. O. Box 234, Cumberland, Md.

1902. STANDARD STEEL WORKS. A. A. Stevenson, Assistant Superintendent, Burnham, Pa.

1903. STAPLETON, F. M. Inspector, Chicago and Northwestern Railway, 504 Smithfield Street, Pittsburg, Pa.

1904. STATTELMANN, G. R. 37 West Washington Street, Dayton, Ohio.

1896. STAUFFER, DAVID MCN. Civil Engineer; Editor, *Engineering News*, 220 Broadway, New York, N. Y.

ELECTED.

1899. Steinman, A. J. Chairman, Pennsylvania Iron Company, Limited, Lancaster, Pa.

1904. *Stevens, J. F. Second Vice-President, Chicago, Rock Island and Pacific Railroad, Chicago, Ill.

1896. Stevenson, A. A. Assistant Superintendent, Standard Steel Works, Burnham, Mifflin County, Pa.

1903. Stewart, Clinton R. Engineer of Tests, Cambria Steel Company, Johnstown, Pa.

1004. Stewart, P. M. Consulting Engineer, The Nevada, Broadway and Seventieth Street, New York, N. Y.

1899. Stillman, Thomas B. Professor of Chemistry, Stevens Institute of Technology, Hoboken, N. J.

1903. Storey, W. B., Jr. Chief Engineer, Atchison, Topeka and Santa Fé Railroad Company, Topeka, Kan.

1904. Stormer, Edw. J. Chemist for the J. I. Case Plow Works, Racine, Wis.

1902. Stoughton, Bradley. Adjunct Professor of Metallurgy and Consulting Metallurgist, Columbia University, New York, N. Y.

1903. Stratton, E. Platt. Chief Engineer Surveyor, American Bureau of Shipping, 66–70 Beaver Street, New York, N. Y.

1903. Streeter, Lafayette P. Engineer of Tests, New York Air-Brake Company, Box 363, Watertown, N. Y.

1896. Strobel, Charles L. Consulting Engineer, 1744 Monadnock Block, Chicago, Ill.

1904 Stuetz, E. Vice-President and Treasurer, The Goldschmidt Thermit Company, 43 Exchange Place, New York, N. Y.

1896. Swain, George F. Professor of Civil Engineering, Massachusetts Institute of Technology, Boston, Mass.

1903. Swanberg, F. L. Mechanical Engineer, The Lukenheimer Company, Cincinnati, O.

1903. Swensson, Emil. Consulting Engineer, Frick Building, Pittsburg, Pa.

1904. Swing, S. Walter. Assistant to Engineer of Tests, Lukens Iron and Steel Company, Coatesville, Pa.

1903. Taggart, Howard. Engineer of Tests, Lukens Iron and Steel Company, P. O. Box 632, Coatesville, Pa.

1898. Talbot, Arthur N. Professor of Municipal and Sanitary Engineering, University of Illinois, Urbana, Ill.

ELECTED.

1902. TALBOT, HENRY P. Professor of Inorganic and Analytical Chemistry, Massachusetts Institute of Technology, Boston, Mass.

1904. TASSIN, WIRT. Chemist; Assistant Curator, National Museum, Washington, D. C.

1904. TAUBENHEIM, ULRICH E. Manager, City Water Works, Archangel, Russia.

1900. TAYLOR, WILLIAM PURVES. Engineer in Charge, Testing Laboratory, 418 City Hall, Philadelphia, Pa.

1896. TECHNISCHER VEREIN, NEW YORK. Carl Kaelble, Secretary, Room 705, 290 Broadway, New York, N. Y.

1896. TECHNISCHER VEREIN, PHILADELPHIA. 534 North Fourth Street, Philadelphia, Pa.

1896. TECHNISCHER VEREIN, PITTSBURG. Gustav A. Stierlin, Secretary, 166 Robinson Street, Pittsburg, Pa.

1896. TECHNISCHER VEREIN, WASHINGTON. Paul Bausch, Corresponding Secretary, 3418 Brown Street, N. W., Washington, D. C.

1902. THACHER, EDWIN. Consulting Engineer; Member, Concrete-Steel Engineering Company, Park Row Building, New York, N. Y.

1904. THAYER AND COMPANY, INCORPORATED. 1015 Tremont Building, Boston, Mass.

1900. THOMAS, DAVID. Assistant to President, Reading Iron Company, Reading, Pa.

1903. THOMPSON, GUSTAVE W. Chemist, National Lead Company, 129 York Street, Brooklyn, N. Y.

1904. THOMPSON, SANFORD E. Civil Engineer, Newton Highlands, Mass.

1904. THOMSON, FRANK K. Superintendent of Construction, Quartermaster's Department, U. S. Army, 185 Middle Street, Portland, Me.

1904. TILLSON, GEO. W. Chief Engineer, Bureau of Highways, Borough of Brooklyn, Municipal Building, Brooklyn, N. Y.

1900. TIPPETT AND WOOD. Plate Iron and Steel Workers, Phillipsburg, N. J.

1903. TOCH, MAXIMILIAN. Paint Manufacturer, 468 West Broadway, New York, N. Y.

1903. TOMKINS, CALVIN. Manufacturer, 17 Battery Place New York, N. Y.

1903. TOUCEDA, ENRIQUE. Chemist and Metallurgist, 51 State Street, Albany, N. Y.

ELECTED.

1904. Trooien, O. N. Assistant in Mechanical Engineering, South Dakota Agricultural College, Brookings, So. Dak.

1902. Turneaure, F. E. Dean of the College of Mechanics and Engineering, University of Wisconsin, Madison, Wis.

1902. Umstead, C. H. Superintendent of Construction, U. S. Public Buildings, 39 Blakeley Building, Lawrence, Mass.

1904. Van Cleve, A. H. Resident Engineer, The Niagara Falls Power Company, Niagara Falls, N. Y.

1903. Van Gundy, C. P. Chief Chemist, Baltimore and Ohio Railroad, Mont Clare, Baltimore, Md.

1902. Van Ornum, J. L. Professor of Civil Engineering, Washington University, St. Louis, Mo.

1903. *Vannier, Charles H. Griffin Wheel Company, Sacramento Square, Chicago, Ill.

1896. Vogt, A. S. Mechanical Engineer, Pennsylvania Railroad, Altoona, Pa.

1904. von Ammon, S. Designing Engineer, British Thomson-Houston Company, Limited, Rugby, England.

1903. Von Schrenk, Hermann. Chief, Division of Forest Products, Bureau of Forestry, U. S. Department of Agriculture, Missouri Botanical Garden, St. Louis, Mo.

1902. Voorhees, S. S. Engineer of Tests, Treasury Department, Washington, D. C.

1903. Vredenburgh, Watson, Jr. Professor of Civil Engineering, Manhattan College, 50 Broadway, New York, N. Y.

1904. Wachter, Charles Lucas. Assistant Engineer, Lidgerwood Manufacturing Company, 96 Liberty Street, New York, N. Y.

1896. Waddell, J. A. L. Consulting Civil Engineer, Kansas City, Mo.

1904. Wagenhorst, James H. Westinghouse Machine Company, Pittsburg, Pa.

1899. Wagner, Samuel Tobias. Assistant Engineer, Philadel phia and Reading Railway, Reading Terminal, Philadelphia, Pa.

1903. Waid, D. Everett. Architect, 156 Fifth Avenue, New York, N. Y.

1904. Waldo Bros. 102 Milk Street, Boston, Mass.

ELECTED.

1902. WALKER, JOSEPH F. Chemist, The Protectus Company, Bridgeport, Pa.

1903. WALKER, R. F. Cement Tester in Charge, Rapid Transit Railway, New York, 412 Turner Street, Allentown, Pa.

1904. WALLACE, E. C. Chemist, Warren Bros. Company, Post Office Box 42, Cambridgeport, Mass.

1903. WALSH, W. F. American Steel Foundries, 712 Hickox Building, Cleveland, O.

1903. WALTER, LEE W. Cement Inspector, Baltimore and Ohio Railroad, B. and O. Cement Laboratory, Wheeling, W. Va.

1904. WARDELL, H. R. General Sales Agent, Barber Asphalt Paving Company, Ardmore, Pa.

1903. WARNER, GEORGE C. Sullivan Machinery Company, P. O. Box 33, Claremont, N. H.

1904. WASON, LEONARD C. President, Aberthaw Construction Company, 8 Beacon Street, Boston, Mass.

1904. WEBB, Z. Chief Chemist, Eliza Furnace, Jones and Laughlins, Limited, Pittsburg, Pa.

1900. WEBSTER, GEORGE S. Chief Engineer and Surveyor, Bureau of Surveys, 418 City Hall, Philadelphia, Pa.

1898. WEBSTER, WILLIAM R. Civil Engineer, 411 Walnut Street, Philadelphia, Pa.

1904. WELLS, J. WALTER. 932 Markham Street, Toronto, Canada.

1903. WEMLINGER, J. R. Engineer, Cambria Steel Company, Westmont, Johnstown, Pa.

1904. WENTWORTH, CHARLES C. Principal Assistant Engineer, Norfolk and Western Railway, Roanoke, Va.

1897. WEST, THOMAS D. Foundry Expert, Sharpsville, Pa.

1904. WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY. L. A. Osborne, Vice-President, Box 911, Pittsburg, Pa.

1900. WHITEHEAD, J. W., JR. Preservative Coatings, 160 Fifth Avenue, New York, N. Y.

1902. WHITNEY, ASA W. Secretary and Metallurgist, Sanford-Day Iron Works, Southern Successors to A. Whitney and Sons' Car Wheel Works, P. O. Box 523, Knoxville, Tenn.

1902. WHITNEY, WILLIS R. Associate Professor of Chemistry, Massachusetts Institute of Technology, Boston, Mass.

1898. WICKHORST, MAX H. Engineer of Tests, Chicago, Burlington and Quincy Railroad, Aurora, Ill.

ELECTED.

1904. Wiebusch, Chas. F. Treasurer, West Indies Company, 9 Murray Street, New York, N. Y.

1904. Wilcox, Lewis G. Inspector of Steel, New York Rapid Transit Railroad Commission, 613 Empire Building, Pittsburg, Pa.

1902. Wilhelm Company, The A. Paint Makers, Reading, Pa.

1903. Wilkins, A. D. Chemist, Bellevue P. O. Station, 8 Sprague Avenue, Allegheny, Pa.

1898. Wille, H. V. Engineer of Tests, Baldwin Locomotive Works, 500 North Broad Street, Philadelphia, Pa.

1904. Williams, Thomas H. President, A. A. Griffing Iron Company, Jersey City, N. J.

1900. Wing, Charles B. Professor of Structural Engineering, Stanford University, Cal.

1904. Wisner, George Y. Consulting Engineer, U. S. Reclamation Service, 34 West Congress Street, Detroit, Mich.

1903. Wittman, N. B. Potts and Wittman, North American Building, Philadelphia, Pa.

1903. Wolfel, Paul L. Chief Engineer, American Bridge Company, Ambridge, Pa.

1902. Wood and Company, R. D., Founders. Walter Wood, 400 Chestnut Street, Philadelphia, Pa.

1903. Wood, Alan D. Superintendent, Alan Wood Iron and Steel Company, Conshohocken, Pa.

1903. Wood, Edward R., Jr. Manufacturer, 400 Chestnut Street, Philadelphia, Pa.

1903. Wood, F. W. President, Maryland Steel Company, Sparrows Point, Md.

1900. Wood, Walter. Cast-Iron Pipe Manufacturer, R. D. Wood Company, 400 Chestnut Street, Philadelphia, Pa.

1903. Woodman, Durand. Analytical and Technical Chemist, 80 Beaver Street, New York, N. Y.

1900. Woolson, Ira H. Adjunct Professor of Mechanical Engineering, Columbia University, New York, N. Y.

1904. Worcester, Joseph R. Consulting Engineer, 53 State Street, Boston, Mass.

1904. Wormeley, P. L., Jr. Engineer of Tests, Division of Tests, U. S. Department of Agriculture, Washington D. C.

1903. Worthington, Charles. Consulting Engineer, 1322 Farmers' Bank Building, Pittsburg, Pa.

ELECTED.

1904. WRIGHT, H. H. Secretary and General Manager, Featherstone Foundry and Machine Company, 348 North Halsted Street, Chicago, Ill.

1902. WYCKOFF, CHARLES, JR. 185 Penn Street, Brooklyn, N. Y.

1904. YAMAMOTO, YOSHIO. Mechanical Engineer, 1324 Twelfth Avenue, Altoona, Pa.

1903. ZEHNDER, C. H. Manager, Rogers, Brown and Warren, Pennsylvania Building, Philadelphia, Pa.

GEOGRAPHICAL DISTRIBUTION OF MEMBERS.

Alabama	3	Maryland	8	Texas	1
Arizona	1	Massachusetts	38	Vermont	1
California	5	Michigan	7	Virginia	16
Colorado	5	Missouri	11	Washington	1
Connecticut	7	Nebraska	1	West Virginia	2
Delaware	2	New Hampshire	1	Wisconsin	15
Dist. of Columbia	25	New Jersey	20	Canada	12
Illinois	44	New York	139	Cuba	1
Indiana	8	North Carolina	3	Germany	2
Iowa	2	Ohio	22	England	3
Kansas	2	Pennsylvania	182	Hawaii	1
Kentucky	2	Rhode Island	2	Russia	1
Louisiana	1	South Dakota	1	Address unknown	1
Maine	2	Tennessee	2		

Total 603

DECEASED MEMBERS.

Name.	Date of Membership.	Date of Death.
W. P. Black	1896	December 12, 1902.
Thomas M. Drown	1899	November 16, 1904.
Henry U. Frankel	1903	December 8, 1903.
Charles Jarecki	1896	January 26, 1901.
J. B. Johnson	1899	June 23, 1902.
G. M. McCauley	1898	May 25, 1901.
George S. Morison	1896	July 1, 1903.
Henry Morton	1896	May 9, 1902.
Robert H. Thurston	1896	October 25, 1903.

PAST OFFICERS.

NOTE.—The Society, from its organization in 1898 till its incorporation under its present name in 1902, was designated the American Section of the International Association for Testing Materials.

The officers and members of the Executive Committee during this four-year period were as follows:

CHAIRMEN:

MANSFIELD MERRIMAN, 1898–1900.

HENRY M. HOWE, 1900–1902.

VICE-CHAIRMEN:

HENRY M. HOWE, 1898-1900.

CHARLES B. DUDLEY, 1900–1902.

SECRETARIES:

RICHARD L HUMPHREY, 1898–1900.

J. M. PORTER, 1900–1902.

TREASURERS:

PAUL KREUZPOINTNER, 1898–1900.

R. W. LESLEY, 1900–1902.

MEMBERS OF EXECUTIVE COMMITTEE:

GUS C. HENNING, 1898–1900.

ALBERT LADD COLBY, 1900–1902.

TECHNICAL COMMITTEES

OF THE

AMERICAN SOCIETY FOR TESTING MATERIALS.

Committee A, on Standard Specifications for Iron and Steel.

William R. Webster, *Chairman.*
Edgar Marburg, *Secretary.*

American Steel and Wire Company,
F. H. Daniels.
Bethlehem Steel Company,
E. O'C. Acker.
Cambria Steel Company,
George E. Thackray.
Carnegie Steel Company,
John McLeod.
Central Iron and Steel Company,
James B. Bailey.
Charles S. Churchill.
James Christie.
F. H. Clark.
J. Allen Colby.
Colorado Fuel and Iron Company,
C. S. Robinson.
John Sterling Deans.
P. H. Dudley.
Franklin Institute,
Alex. E. Outerbridge, Jr.
J. E. Greiner.
Robert W. Hunt Company.
Illinois Steel Company,
P. E. Carhart.
Jones and Laughlins, Limited,
Willis L. King.
Gaetano Lanza.
Lukens Iron and Steel Company,
Charles L. Huston.
Edgar Marburg.
S. S. Martin.
Richard Moldenke.
National Tube Company,
Taylor Allderslice.
L. R. Pomeroy.
The Osborn Engineering Company,
Frank C. Osborn.
The Pennsylvania Steel Company,
H. H. Campbell.
Reading Iron Company,
David Thomas.
Joseph T. Richards.
John A. Roebling's Sons Company,
J. H. Janeway.
C. C. Schneider.
Shelby Steel Tube Company,
J. H. Nicholson.
J. P. Snow.
Standard Steel Works,
A. A. Stevenson.
J. A. L. Waddell.
Samuel T. Wagner.
William R. Webster.
Max H. Wickhorst.
H. V. Wille.
R. D. Wood and Company,
Walter Wood.

Committee B, on Standard Specifications for Cast Iron and Finished Castings.

Walter Wood, *Chairman.*
Richard Moldenke, *Secretary.*

Hugh W. Adams.
James A. Beckett.
Robert Bentley.
Joseph W. Bramwell.
H. H. Campbell.
Colorado Fuel and Iron Company,
C. S. Robinson.
Albert Ladd Colby.

COMMITTEE B.—*Continued.*

Edgar S. Cook.
H. A. Croxton.
George M. Davidson.
H. E. Diller.
J. K. Dimmick.
W. C. Du Comb.
Charles B. Dudley.
George F. Eldridge.
B. F. Fackenthal
L. M. Fenner.
H. E. Field.
A. I. Findley.
Stanley G. Flagg, Jr.
W. K. Hatt.
W. H. Hearne.
J. O. Henshaw.
P. S. Hildreth.
Henry M. Howe.
Illinois Steel Company,
P. E. Carhart.
R. Job.
Jones and Laughlins, Limited,
Willis L. King.
W. J. Keep.
J. F. Kinkead.
P. Kreuzpointner.
G. Lanza.
L. R. Lemoine.
William W. Lobdell.
A. E. Loudon.
McCormick Division, International Harvester Company,
F. A. Flather.
Charles F. McKenna.
J. W. McQueen.
R. S. MacPherran.
Mansfield Merriman.
Richard Moldenke.
Tinius Olsen.
Alex. E. Outerbridge, Jr.
Leonard Peckitt.
L. S. Randolph.
David Reid.
Walter M. Saunders.
Albert Sauveur.
W. G. Scott.
C. W. Sherman.
A. W. Slocum.
Henry Souther.
H. W. Spangler.
Technischer Verein, Brooklyn,
B. Viola.
Technischer Verein, Pittsburg,
S. H. Stupakoff.
Enrique Touceda.
C. H. Vannier.
W. R. Webster.
Thomas D. West.
Asa W. Whitney.
H. V. Wille.
N. B. Wittman.
F. W. Wood.
E. R. Wood, Jr.
Walter Wood.
I. H. Woolson.
C. H. Zehnder.

COMMITTEE C, ON STANDARD SPECIFICATIONS FOR CEMENT.

GEORGE F. SWAIN, *Chairman.*
GEORGE S. WEBSTER, *Vice-Chairman.*
RICHARD L. HUMPHREY, *Secretary.*

Booth, Garrett & Blair.
C. W. Boynton.
Spencer Cosby.
A. W. Dow.
L. Henry Dumary.
W. S. Eames.
A. F. Gerstell.
Edward M. Hagar.
W. H. Harding.
Olaf Hoff.
Richard L. Humphrey.
W. J. Kelly.
Lathbury and Spackman.
Robert W. Lesley.
F. H. Lewis.
John B. Lober.
Andreas Lundteigen.
Charles F. McKenna.
W. W. Maclay.
Charles A. Matcham.
Spencer B. Newberry.
James Madison Porter.
Joseph T. Richards.
Clifford Richardson.
L. C. Sabin.
Harry J. Seaman.
George F. Swain.
S. S. Voorhees.
George S. Webster.

COMMITTEE D, ON STANDARD SPECIFICATIONS FOR PAVING AND BUILDING BRICK.

LOGAN WALLER PAGE, *Chairman.*

Ira O. Baker.
Edward Orton, Jr.
W. D. Richardson.
Arthur N. Talbot.

COMMITTEE E, ON PRESERVATIVE COATINGS FOR IRON AND STEEL.

S. S. VOORHEES, *Chairman.*
JOSEPH F. WALKER, *Secretary.*

W. A. Aiken.
The Joseph Dixon Crucible Company,
Malcolm MacNaughton.
Charles B. Dudley.
N. F. Harriman.
International Acheson Graphite Company,
C. L. Collins.
Robert Job.
Spencer B. Newberry.
Charles L. Norton.
Patterson-Sargent Company,
W. A. Polk.
W. A. Powers.
A. H. Sabin.
G. W. Thompson.
S. S. Voorhees.
Joseph F. Walker.
J. W. Whitehead, Jr.
Max H. Wickhorst.
The A. Wilhelm Company,
Charles J. Davies

COMMITTEE F, ON HEAT TREATMENT OF IRON AND STEEL.

Henry M. Howe.
Albert Sauveur.

COMMITTEE G, ON THE MAGNETIC TESTING OF IRON AND STEEL.

J. WALTER ESTERLINE, *Chairman.*

John A. Capp.
H. E. Diller.
J. Walter Esterline.
W. A. Layman.
Richard Moldenke.
J. A. Mathews.

COMMITTEE H, ON STANDARD TESTS FOR ROAD MATERIALS.

LOGAN WALLER PAGE, *Chairman.*
ARTHUR N. JOHNSON, *Secretary.*

Ira O. Baker.
A. Cushman.
A. W. Dow.
A. B. Fletcher.
W. S. Godwin.
G. B. Hemstreet.
J. A. Holmes.
Jos. W. Hunter.
Arthur N. Johnson.
C. A. Kenyon.
Frederic A. Kummer.
Nelson P. Lewis.
J. H. MacDonald.
J. J. Morrow.
Logan Waller Page.
Clifford Richardson.
Thomas B. Stillman.
George W. Tillson.
Calvin Tomkins.
E. C. Wallace.

COMMITTEE I, ON REINFORCED-CONCRETE.

F. E. TURNEAURE, *Chairman.*
R. W. LESLEY, *Vice-Chairman.*
RICHARD L. HUMPHREY, *Secretary.*

W. B. Fuller.
E. Lee Heidenreich.
R. L. Humphrey.
A. L. Johnson.
G. Lanza.
R. W. Lesley.
Edgar Marburg.
C. M. Mills.
L. S. Moisseff.
H. H. Quimby.
W. P. Taylor.
S. E. Thompson.
F. E. Turneaure.
S. T. Wagner.
G. S. Webster.

COMMITTEE J, ON STANDARD SPECIFICATIONS FOR FOUNDRY COKE.

WALTER WOOD, *Chairman pro tem.*
RICHARD MOLDENKE, *Secretary pro tem.*
(In course of organization.)

COMMITTEE K, ON STANDARD METHODS OF TESTING.

GAETANO LANZA, *Chairman pro tem.*
(In course of organization.)

COMMITTEE L, ON STANDARD SPECIFICATIONS AND TESTS FOR SEWER PIPES.

CHARLES F. MCKENNA, *Chairman pro tem.*
(In course of organization.)

COMMITTEE M, ON STANDARD SPECIFICATIONS FOR STAYBOLTS.

H. V. WILLE, *Chairman pro tem.*
(In course of organization.)

COMMITTEE N, ON STANDARD TESTS FOR LUBRICANTS.

W. M. DAVIS, *Chairman pro tem.*
(In course of organization.)

COMMITTEE O, ON UNIFORM SPEED IN COMMERCIAL TESTING.

PAUL KREUZPOINTNER, *Chairman pro tem.*
(In course of organization.)

COMMITTEE P, ON FIRE-PROOFING MATERIALS.

IRA H. WOOLSON, *Chairman pro tem.*

(In course of organization.)

COMMITTEE Q, ON STANDARD SPECIFICATIONS FOR THE GRADING OF STRUCTURAL TIMBER.

HERMANN VON SCHRENK, *Chairman pro tem.*

(In course of organization.)

COMMITTEE R, ON BOILERS.

H. W. SPANGLER, *Chairman.*

F. B. Allen.
R. C. Carpenter.
J. H. Hartley.
Chas. L. Huston.
John McLeod.
E. D. Meier.
Mutual Boiler Insurance Company,
R. S. Hale.
J. E. Sague.
H. V. Wille.

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE.

Since the Sixth Annual Meeting of the Society, the Executive Committee has held four regular quarterly meetings and one special meeting. One of the regular meetings was informal by reason of the absence of a quorum. An abstract of the minutes of these meetings is appended to this report.

The Society's progress during the past year is most encouraging. The membership has grown from 349 to 485. The Proceedings of the last annual meeting yielded a volume of 490 pages, which attracted wide and favorable attention both in this country and abroad. The sale of publications for the year has increased more than three-fold. Several of the more important technical committees have shown great activity during the year, and will submit their reports at this meeting. The appeal of the Executive Committee for financial support met with prompt and generous response, as set forth in detail below.

New Committees.—The list of technical committees has been increased, partly in pursuance of action at the last annual meeting, as follows:

Committee H. On Standard Tests for Road Materials.

Committee I. On Steel-Concrete.

Committee J. On Corrosion of Metals.

Committee K. On Standard Tests for Boilers.

At the request of the Committee on Bitumen, that committee has been discharged. The number of technical committees is now eleven.

Publications.—In addition to the annual volume of the Proceedings (Vol. III, 490 pp.) a pamphlet of 79 pages, containing the list of members and other data relative to the Society, was issued, as well as eight official circulars of information.

Membership.—The membership at the last annual meeting, was 349. Since then 166 new applications for membership have been received and approved. The Society has sustained a loss of three members through death: George S. Morison died on July 1, 1903; Robert H. Thurston, on October 25, 1903, and Henry U. Frankel, on December 8, 1903. The number of resignations for the year is 14, and 13 members were dropped for arrears in dues. The new By-Laws enabling the Executive Committee to drop

delinquents became operative during the year. Of the 13 members dropped, 10 were in arrears for more than one year. The total loss from all causes is 30, leaving a net gain of 136 for the year, and making the total membership at present 485.

Finances.—The financial condition of the Society may be judged from the following report for the year on the part of the Treasurer. The cash balance is $469.68, and there are no unpaid bills on hand.

ANNUAL REPORT OF THE TREASURER.

From June 30, 1903, to June 10, 1904.

RECEIPTS.

Membership dues	$1,437 50	
Dues, contributing members	1,250 00	
Subscriptions	1,857 17	
Sales of publications	182 84	
Reprints	122 38	
Orders for binding	65 50	
International Congress fees	157 50	
Sale of electrotypes	2 70	
Excess remittances	125 80	
Interest on deposits	14 29	
Total receipts	$5,215 68	
Cash balance, June 30, 1903	263 27	
		$5,478 95

DISBURSEMENTS.

Membership dues, International Association	$706 50	
Printing, engraving, binding, stationery, etc.	1,912 33	
Secretary's salary	1,500 00	
Clerical services	212 50	
Expenses Secretary's office	239 00	
Stenographer, Sixth Annual Meeting	135 69	
Committee expenses	20 00	
International Congress fees refunded	157 50	
Excess remittances refunded	125 75	
Total disbursements	$5,009 27	
Cash balance, June 10, 1904	469 68	
		$5,478 95

The lists of Contributing Members and Subscribers follow:

CONTRIBUTING MEMBERS.

Ajax Metal Company,
Anderson, J. W.,
Booth, Garrett and Blair,
Cambria Steel Company,
Carnegie Steel Company,
Central Iron and Steel Company,
Dixon, R. M.,
Dudley, Charles B.,
Goodnow, C. A.,representing the Chicago and Alton Railroad,
Hammond, R. R., representing the St. Louis and San Francisco Railroad,
Harahan, J. T., representing the Illinois Central Railroad,
Illinois Steel Company,
Jones and Laughlins, Limited,
Latrobe Steel Company,
Lesley, R. W.,
Lowe, Houston,
Lukens Iron and Steel Company,
McLeod, John,
Metcalf, William,
Mitchell, Joseph,
Orford Copper Company,
Pennsylvania Steel Company,
Polk, W. A ,
Stevens, J. F., representing the Chicago, Rock Island and Pacific Railroad.
Vannier, C. H.,

Total 25

SUBSCRIBERS.

Bailey, J. B.	$5 00
Baltimore and Ohio Railroad	50 00
Cambria Steel Company	50 00
Christie, James	50 00
Cook, Edgar S.	25 00
Corthell, E. L.	10 00
De Armond, W. C.	25 00
Hunt, Robert W. Company	50 00
International Acheson Graphite Company	10 00
Larsson, C. G. E.	17 00
Lobdell, W. W.	25 00
Long Island Railroad	25 00
Matcham, Chas. A.	25 00
Moldenke, R. G.	10 48
Ostrom, J. N.	5 00
Pennsylvania Railroad	200 00
Pennsylvania Steel Company	211 69
Saunders, Walter M.	5 00
Scarborough, F. W.	5 00
Schneider, C. C.	50 00
Scott, W. G.	20 00
Stapleton, F. M.	3 00

Stevenson, A. A.	$5 00
United States Steel Corporation	950 00
Wood, Walter	25 00
	$1,857 17

In order that the Society may become self-sustaining as soon as possible, the Executive Committee proposes to introduce an amendment to the By-Laws, designed to increase the annual membership dues from $3 to $5.

Relations with the International Association for Testing Materials.—The relations of the Society with the International Association during the past year have been limited practically to routine correspondence. At the instance of the International Association three circulars containing announcements relative to the proposed St. Petersburg Congress and the publications of affiliated national societies have been distributed among our members. The last Congress was held in Buda-Pesth, September 9–14, 1901. The next Congress, which was originally to be held at St. Petersburg in 1903, has been twice postponed, first till 1904, then till 1905. The second postponement was occasioned by the war between Russia and Japan. During the past four years the Society has remitted the sum of $1,916.50 to the International Association, for which practically no returns have been received. The American membership is now far ahead of the membership in any other country, and our remittances to the International Association are now at the rate of over $700 per annum.

The International Association having finally abandoned the plan of establishing an international sidero-chemical laboratory, the American subscribers to the funds raised some years ago for the above purpose, viz: The Pennsylvania Steel Company and Dr. Richard Moldenke, very generously agreed to donate these subscriptions, with accumulated interest, to the treasury of the Society.

In the matter of publications on the part of the International Association, concerning which so much dissatisfaction has been felt in this country, the plan announced for the St. Petersburg Congress was as follows:

> The reports of Committees and Referees on technical subjects are to be translated in three languages, English, German and French, and sent to every member of the Association, free of charge, in whatever language he prefers.

Scientific papers of a non-official character are to be printed in their original language, followed by abridged summaries in three languages. Such papers are to be supplied free of charge to members in attendance at the Congress, and sold at the rate of $2.50 for the set, to members in general.

While the above proposition is perhaps as liberal as can be reasonably expected under present financial conditions, the value of the returns, both in content and in point of translation, can not be judged till the plan has been put to a practical test.

Submitted on behalf of the Executive Committee,

EDGAR MARBURG, *Secretary.*

CHARLES B. DUDLEY, *President.*

REPORT OF AUDITING COMMITTEE.

PHILADELPHIA, June 10, 1904.

To the Executive Committee of the American Society for Testing Materials:

We have examined the books and accounts of the Secretary-Treasurer from January 2, 1904, the date of the last audit, to June 10, 1904, the date of the annual report of the Treasurer, and find the cash balance of $469.68 to be correct.

[Signed] R. W. LESLEY,
J. A. COLBY,
Auditing Committee.

APPENDIX.

ABSTRACT OF MINUTES OF THE EXECUTIVE COMMITTEE.

REGULAR MEETING, July 3, 1903.—Hotel Kittatinny, Delaware Water Gap, Pa. Present: Messrs. Dudley, Lesley, Christie, Colby and Marburg.

The Secretary reported the receipt of 41 applications for membership, duly approved, and the loss of one member by death—W. P. Black, who died on December 12, 1902, making the total membership 349.

The Secretary was instructed to notify members in arrears for dues that unless their dues were paid on or before August 1, 1903, they would become subject to the provisions of the By-Laws with respect to delinquents.

A report was received from the Auditing Committee, consisting of Mr. R. W. Lesley and Mr. James Christie, to the effect that the cash balance of $263.27 on July 1, 1903, was found correct.

REGULAR MEETING, October 10, 1903.—Engineers' Club of Philadelphia, 1122 Girard Street, Philadelphia, Pa. Present: Messrs. Dudley, Christie and Marburg of the Executive Committee, and Mr. W. R. Webster on invitation.

In the absence of a quorum it was decided to hold an informal meeting, with the understanding that any action taken would be subject to the approval of the Executive Committee at its next meeting.

The Secretary reported the receipt of 49 applications for membership, duly approved, the dropping of 10 members for arrears in dues, and the loss of one member by death, Geo. S. Morison, who died July 1, 1903, making the total membership 387.

The Secretary reported that the letter ballot on the proposed amendments of the By-Laws according to the resolutions passed at the annual meeting, had resulted favorably; the amendments in question being as follows:

1. That Section 3, Article 1, be designated Section 4.

2. That a new Section 3 be inserted, viz.: Any member who subscribes annually the sum of fifty dollars ($50) toward the general funds of the Society shall be designated a Contributing Member, his rights and privileges as a member remaining unchanged.

It was decided that the price of previous publications to members be fixed at $2.00 per volume.

The following action was taken on the matters referred to the Executive Committee at the Sixth Annual Meeting:

1. It was resolved to appoint a committee on "Standard Specifications for the Testing of Road Materials"

2. Favorable action was taken on the question of co-operation with other societies toward bringing about a modification of the laws governing the inspection of steamboat and steamship boilers.

3. The recommendation of the committee on Bitumen that it be discharged, was approved.

Action on the following resolutions passed at the Annual Meeting was deferred:

1. That the Executive Committee be requested to consider the desirability of appointing a committee on "Reinforced Concrete," with a view of co-operating with committees of other societies in the study of that subject.

2. That the question as to what, if anything, should be done by way of studying the behavior of metal subjected to alternate stresses be referred to the Executive Committee with power.

SPECIAL MEETING, December 5, 1903.—Engineers' Club of Philadelphia, 1122 Girard Street, Philadelphia, Pa. Present: Messrs. Dudley, Christie, Lesley, McLeod and Marburg of the Executive Committee, and Mr. Wm. R. Webster on invitation.

The action taken at the last quarterly meeting on October 10, in the absence of a quorum, was formally approved.

The following resolution off red at the Annual Meeting: "That the Executive Committee be requested to consider the desirability of appointing a committee on "Reinforced Concrete," with a view of co-operating with committees of other societies in the study of the subject," on which action was deferred at the last meeting, was duly considered and approved.

It was decided to defer action on the question of appointing a committee on the investigation of alternate stresses, pending further inquiry which the Secretary was instructed to make.

In pursuance of an inquiry on the part of the chairman of one of the technical committees, the following resolutions were passed applicable to technical committees in general:

1. That the Society cannot assume the traveling expenses of members.

2. That applications for financial aid for the prosecution of committee work shall receive due consideration, provided that a detailed program accompanied by a cost estimate be submitted.

A report on "The Grading of Cast Iron," received from Committee B, was referred to Committee A.

It was decided to appoint a committee on "The Corrosion of Metals."

REGULAR MEETING, January 9, 1904.—Engineers' Club of Philadelphia, 1122 Girard Street, Philadelphia, Pa. Present: Messrs. Dudley, Lesley, Christie and Marburg.

The Secretary reported the receipt of 29 applications for membership, duly approved, five resignations and the loss of one member by death, Robert H. Thurston, who died on October 25, 1903, making the total membership 411.

The Auditing Committee, consisting of Messrs. R. W. Lesley and W. R. Webster, announced that they had duly examined the accounts of the Treasurer and that they had found the balance of $646.18 on December 31, 1903, correct.

It was decided to interpret the By-Laws as exempting the Contributing Members from the annual dues of $3.00 and to distinguish the names of such members in the published membership list by an asterisk.

The Secretary was instructed to insert a printed list of Contributing Members and of Subscribers, together with the amounts subscribed, in the annual report of the Executive Committee.

The Secretary presented a letter from President Tetmajer expressing the hope that this Society would undertake the work of translating the St. Petersburg papers and committee reports from French and German into English. After due consideration it was decided that this work might reasonably be expected to be handled under the direct auspices of the International Association, especially as the cost would thereby be considerably reduced. The Secretary was accordingly instructed to advise President Tetmajer that the Executive Committee deemed it inexpedient to undertake this work.

REGULAR MEETING, April 2, 1904.—Engineers' Club of Philadelphia, 1122 Girard Street, Philadelphia, Pa. Present: Messrs. Dudley, Lesley, Christie and Marburg.

The Secretary reported the receipt of 36 applications for membership, duly approved, seven resignations and the loss of one member by death, Henry Frankel, who died on December 8, 1903, making the total membership 439.

The Secretarywas instructed to make suitable acknowledgment on behalf of the Executive Committee to Contributing Members and Subscribers and also to send each Contributing Member a complimentary bound copy of Volume III.

It was decided to hold the Seventh Annual Meeting at Atlantic City, N. J., on June 16-18, 1904.

It was resolved to offer an amendment at the Annual Meeting to Article 4, Section 2, of the By-Laws, relative to dues, increasing the same from $3.00 to $5.00 per annum.

It was decided to increase the price of Bulletins 4 to 28 inclusive, from 10 cts. each to 15 cts. each, or $2.50 for a complete set of twenty-five numbers. The special price to members was fixed at 10 cts. per copy, or $1.50 for the set.

The enlarged membership of the various technical committees as printed in Volume III of the Proceedings, was formally approved.

It was decided to appoint a committee on Standard Tests for Boilers.

It was agreed that members whose resignation was not received on or before February 1, should be held responsible for the dues of the year.

The Secretary reported that the project for the establishment of an International Sidero-Chemical Laboratory had been abandoned and that the subscriptions for that purpose were to be refunded to the contributors. The Secretary was instructed to invite the American contributors to turn over these subscriptions to the treasury of the Society.

Favorable action was taken on the suggestion of President Tetmajer that letters of invitation be addressed to the leading American scientific and technical societies to appoint delegates to the St. Petersburg Congress.

The Secretary submitted a letter from Mr. F. R. Hutton, Secretary of the American Society of Mechanical Engineers, relative to the probability of the Society acquiring space in the proposed "Union Engineering Building." The Secretary was instructed to reply that it was not deemed expedient at present to make such application, but that if at some future time the conditions should be more favorable to such a step, the Executive Committee would be glad to avail itself of the invitation.

The Secretary submitted a letter from Mr. Wm. R. Webster recommending that the Standard Specifications for Iron and Steel be printed in pamphlet form. Action on this recommendation was deferred pending further inquiry as to the likelihood of amendments to these specifications within the near future.

PREVIOUS PUBLICATIONS.

TABLE OF CONTENTS.

NOTE.—The Society, from its organization in 1898 till its incorporation under its present name in 1902 was designated the American Section of the International Association for Testing Materials. During this period twenty-eight (28) Bulletins were issued, which, collectively, constitute Volume I. of the Proceedings. In 1900 it was decided to publish the Proceedings in the form of annual volumes. Volume II., containing 388 pages, is the first volume of this new series. Volume III., issued in 1903, contains 490 pages. An abridged Table of Contents follows.

VOLUME I.

Bulletin No. 1. *Issued April*, 1899. Pp. 1–8.
Minutes of the Organization Meeting, June 16, 1898.
Minutes of the Executive Committee, June 25, 1898, to February 22, 1899.
Minutes of First Annual Meeting, August 27, 1898.

Bulletin No. 2. *Issued July*, 1899. Pp. 9–12.
Provisional Program for the Second Annual Meeting.

Bulletin No. 3. *Issued August*, 1899. Pp. 13–16.
Officers of the American Section.
Program of the Second Annual Meeting.

Bulletin No. 4. *Issued September*, 1899. Pp. 17–26.
The work of the International Association for Testing Materials. Annual Address by the Chairman, Professor Mansfield Merriman.

Bulletin No. 5. *Issued October*, 1899. Pp. 27–52.
Preliminary Report on the Present State of Knowledge Concerning Impact Tests, by Professors W. Kendrick Hatt and Edgar Marburg.

Bulletin No. 6. *Issued November*, 1899. Pp. 53–72.
Report of Second Annual Meeting, August 15–16, 1899.
Minutes of the Executive Committee to August 16, 1899.

Bulletin No. 7. *Issued January*, 1900. Pp. 73–80.
Minutes of the Executive Committee to January 6, 1900.
Miscellaneous Announcements.

Bulletin No. 8. *Issued May*, 1900. Pp. 81–86.
Proposed Standard Specifications for Structural Steel for Bridges and Ships.

Bulletin No. 9. *Issued May*, 1900. Pp. 87–92.
Proposed Standard Specifications for Structural Steel for Buildings.

Bulletin No. 10. *Issued May*, 1900. Pp. 93–100.
Proposed Standard Specifications for Open-hearth Boiler Plate and Rivet Steel.

Bulletin No. 11. *Issued May*, 1900. Pp. 101–106.
Proposed Standard Specifications for Steel Rails.

Bulletin No. 12. *Issued May*, 1900. Pp. 107–110.
Proposed Standard Specifications for Steel Splice Bars.

Bulletin No. 13. *Issued May*, 1900. Pp. 111–114.
Proposed Standard Specifications for Steel Axles.

Bulletin No. 14. *Issued May*, 1900. Pp. 115–118.
Proposed Standard Specifications for Steel Tires.

Bulletin No. 15. *Issued May*, 1900. Pp. 119–124.
Proposed Standard Specifications for Steel Forgings.

Bulletin No. 16. *Issued May*, 1900. Pp. 125–128.
Proposed Standard Specifications for Steel Castings.

Bulletin No. 17. *Issued May*, 1900. Pp. 129–134.
Proposed Standard Specifications for Wrought Iron.

Bulletin No. 18. *Issued May*, 1900. Pp. 135–144.
Report of the American Branch of International Committee No. 1.

Bulletin No. 19. *Issued September*, 1900. Pp. 145–172.
Program of the Third Annual Meeting.
Minutes of the Executive Committee, April 7, 1900.
Correspondence Relating to the Representation of the American Section on the International Council.

Bulletin No. 20. *Issued October*, 1900. Pp. 173–184.
Progress Report of the American Branch of International Committee No. 1.

Bulletin No. 21. *Issued March*, 1901. Pp. 185–214.
Announcement of International Congress of 1901.
Report of Third Annual Meeting, October 25–27, 1900.
Minutes of the Executive Committee to January 5, 1901.
Officers of the American Section for 1900–02.

Bulletin No. 22. *Issued May*, 1901. Pp. 215–216.
Program of the Fourth Annual Meeting.

Bulletin No. 23. *Issued June*, 1901. Pp. 217–230.
List of Members of the American Section.
By-Laws of the American Section.

Bulletin No. 24. *Issued June*, 1901. Pp. 231–236.
Revised Standard Specifications for Wrought Iron.

Bulletin No. 25. *Issued June*, 1901. Pp. 237–244.
Report of the American Branch of International Committee No. 1.

Bulletin No. 26. *Issued July*, 1901. Pp. 245–246.
Letter Ballot on Proposed Standard Specifications.

Bulletin No. 27. *Issued August*, 1901. Pp. 247–262.
Report of Fourth Annual Meeting, June 29, 1901.

Bulletin No. 28. *Issued May*, 1902. Pp. 263–266.
Program of the Fifth Annual Meeting.

VOLUME II.

Summary of Proceedings of the Fifth Annual Meeting.

Annual Address by the Retiring President, Henry M. Howe.

Proposed Modifications of the Standard Specifications for Steel Rails. Topical Discussion.

Is it Desirable to Specify a Single Grade of Structural Steel for Bridges of Ordinary Spans? Topical Discussion.
Formal Discussion: A. P. Boller, T. L. Condron, Theodore Cooper, J. E. Greiner, John McLeod, C. C. Schneider, J. P. Snow.

Rail Temperatures. Simon Strock Martin.

Finishing Temperature and Structure of Steel Rails. Albert Sauveur.

The Relation between the Basic Open-hearth Process and the Physical Properties of Steel. Topical Discussion.

Steel Rivets. Gaetano Lanza.

The Ethics of Testing. Paul Kreuzpointner.

Standard Cement Specifications. R. W. Lesley.

The Advantages of Uniformity in Specifications for Cement and Methods of Testing. George S. Webster.

The Chemical Analysis of Cement: Its Possibilities and Limitations. Richard K. Meade.

Cement Testing in Municipal Laboratories. Richard L. Humphrey.

Tests of Reinforced Concrete Beams. W. Kendrick Hatt.

Effect of Variation in the Constituents of Cast Iron. W. G. Scott.

Present Status of Testing Cast Iron. Richard G. Moldenke.

The Need of Foundry Experience for the Proper Inspection and Testing of Cast Iron. Thos. D. West.

A Quick and Automatic Taper Scale Test. Asa W. Whitney.

High Strength of White Iron Castings as Influenced by Heat Treatment. Alex. E. Outerbridge, Jr.

Notes on Current Specifications for Cast Iron Pipe. Walter Wood.

On the Constitution of Cast Iron. Henry M. Howe.

APPENDICES.

Appendix I. Report on the Buda-Pesth Congress. Henry M. Howe.

Appendix II. Bibliography on Impact Tests and Impact Testing Machines. W. Kendrick Hatt and Edgar Marburg.

Appendix III. Rules for Standard Tests of Materials Formulated by the German Association for Testing Materials (English Translation).

VOLUME III.

Summary of Proceedings of the Sixth Annual Meeting.

The Making of Specifications—Annual Address by the President, Charles B. Dudley.

Report of Committee "A" on Standard Specifications for Iron and Steel.

Report of Committee "B" on Standard Specifications for Cast Iron and Finished Castings.

Report of Committee "C" on Standard Specifications for Cement.

Report of Committee "E" on Preservative Coatings for Iron and Steel.

Report of Committee "G" on the Magnetic Properties of Iron and Steel.

Specifications for Iron and Steel Structures Adopted by the American Railway Engineering and Maintenance of Way Association, in March, 1903, with Introduction by J. P. Snow, Chairman.

Specifications for Locomotive Axles and Forgings, Recommended by a Committee of the American Railway Master Mechanics' Association, in June, 1903, with Introduction by F. H. Clark, Chairman.

Specifications for Steel Rails Adopted by the American Railway Engineering and Maintenance of Way Association, in March, 1902, and the Modifications Submitted in March, 1903; William R. Webster, Chairman.

Specifications for Boiler Plate, Rivet Steel, Steel Castings, and Steel Forgings, Recommended by a Committee of the American Society of Mechanical Engineers; H. W. Spangler, Chairman.

Manufacturers' Standard Specifications as Revised in February, 1903, and Their Comparison with Other Recent Prominent Specifications. Albert Ladd Colby.

The Requirements for Structural Steel for Ship-building Purposes. Topical Discussion, opened by E. Platt Stratton.

Springs and Spring Steels. William Metcalf.

The Rolling of Piped Rails. Topical Discussion, opened by Albert Sauveur and Robert Job.

The Casting of Pipeless Ingots by the Sauveur Overflow Method. Albert Sauveur and Jasper Whiting.

Nickel Steel: Its Properties and Applications. Albert Ladd Colby.

Alternate Stresses in Bridge Members. Gustav Lindenthal.

The Constitution of Cast Iron. William Campbell.

Machine-cast Sandless Pig Iron in Relation to the Standardizing of Pig Iron for Foundry Purposes. Edgar S. Cook.

The Physical Properties of Malleable Castings as Influenced by the Process of Manufacture. Richard G. Moldenke.

Cast Iron: A Consideration of the Reactions Which Make it Valuable. Herbert E. Field.

The Importance of Adopting Standard Sizes of Test Bars for Determining the Strength of Cast Iron. Alexander E. Outerbridge, Jr.

The Demand for a Specified Grade of Cast Iron. W. G. Scott.

Cast Iron for Dynamo and Motor Frames. H. E. Diller.

The Light Aluminium Alloys. J. W. Richards.

The Testing of Bearing Metals. G. W. Clamer.

The Master Car Builders' Drop-testing Machine as Installed at Purdue University. W. F. M. Goss.

Stremmatograph Tests of Unit Fiber Strains and Their Distribution in the Base of Rails under Moving Locomotives, Cars, and Trains. P. H. Dudley.

The Control of the Finishing Temperature of Steel Rails by the Thermo-magnetic Selector. Albert Sauveur and Jasper Whiting.

A Direct-reading Apparatus for Determining the Energy Losses in Transformer Iron. J. Walter Esterline.

The United States Road Material Laboratory: Its Aims and Methods. L. W. Page and A. Cushman.

A Preliminary Program for the Timber Test Work to be Undertaken by the Bureau of Forestry, United States Department of Agriculture. W. K. Hatt.

A Brief Account of the History and Methods of the International Railway Congress. P. H. Dudley.

The Testing of Bitumens for Paving Purposes. A. W. Dow.

Soundness Tests of Portland Cement. W. P. Taylor.

Portland Cement Mortar Exposed to Cold. C. S. Gowen.

Some Observations on the Effect of Water and Combinations of Sand upon the Setting Properties and Tensile Strength of Portland and Natural Cements. E. S. Larned.

Tests on the Compressive Strength of Concrete and Mortar Cubes. C. H. Umstead.

PRICE LIST.

Volume I., containing Bulletins Nos. 1 to 28, inclusive (266 pp.)	$3 00
Separate Bulletins	15
Volume II., (388 pp.)	5 00
Volume III., (490 pp.)	5 00
Volume IV., (655 pp.)	5 00

Libraries, publishers and book-dealers are allowed a discount of 20 per cent. on the above prices.

Members of the Society may obtain back publications for the completion of their personal files at the following special prices:

Volume I	$2 00
Volumes II., III. and IV., price per volume	3 00

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

OFFICERS.

PRESIDENT.

L. VON TETMAJER.

VICE-PRESIDENTS.

A. MARTENS, N. BELELUBSKI.

MEMBERS OF COUNCIL.

Every country having a membership of twenty or more in the Association is entitled to a representative on the Council.

Austria—F. BERGER.
Belgium—A. GREINER.
Denmark—J. HANNOVER.
England—T. E. STEAD.
France—A. MESNAGER
Germany—A. MARTENS.
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Switzerland—F. SCHUELE.
United States of America—CHARLES B. DUDLEY.

SECRETARY.

ERNEST REITLER,
Vienna, Austria.

Communications for the International Association should be directed to the President, Professor L. von Tetmajer, Imperial Technical High School, Karlsplatz, Vienna, IV, Austria.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

BY-LAWS.

Adopted at the Buda-Pesth Congress, 1901.

SECTION 1. The Association shall be called "THE INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS."

SEC. 2. The objects of the Association are: the development and unification of standard methods of testing; the investigation of the technically important properties of the materials of construction and other materials of technical importance, and also the perfecting of apparatus used for this purpose.

These objects will be furthered:

1. By the Congresses and other meetings of the Association.
2. By the publication of an official Journal.
3. By any other means that may appear desirable.

SEC. 3. The funds necessary for carrying out the purposes mentioned in Section 2 will be raised by

1. The annual subscriptions of members.
2. Profits from the official Journal.
3. Other contributions.

SEC. 4. Any person may become a member upon being proposed by two members of the Association.

Official bodies and technical societies can be elected directly on their sending in their application for membership.

Applications for membership must be sent in writing to the President or to a member of the Council.

Resignations of membership must be sent in the same way.

SEC. 5. It is the duty of every member to further the interests of the Society to the best of his ability.

Every member is required to pay an annual subscription of at least 6 Mks.= 6 shillings = $1.50.*

The Council is authorized to increase the annual subscription in order to cover extraordinary expenses incurred in the interests of the Association.

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* Subscriptions are to be paid to the duly appointed collectors in each country, the card of membership serving as a receipt. Subscriptions not paid by the first of July are collected through the post-office.

SEC. 6. Every member has the right to obtain the Journal of the Association, during the period for which his subscription has been paid, on paying the fixed reduced price.*

SEC. 7. The Association will hold a Congress, as a rule, every second year.

The arrangements for the Congresses will be discussed at general meetings and in meetings of the different sections.

Sections will be formed for the different groups of materials as may be considered necessary.

At present there are three sections:

I. Metals.

II. Natural and artificial building stones, cements and mortars.

III. Other materials of technical value.

Any special questions relating to the subjects of the different sections will be considered at sectional meetings.

The members assisting at the sectional debates, under the presidency of a member of the Council, will appoint the governing bodies of the different sections.

The results of the deliberations of the different sections must be communicated at a general meeting which will pass resolutions embodying the proposals of the sections.

Reports of Commissions, proposals of the Council and other matters to be laid before the Congress, will be printed in German, French and English, and will be sent (in the language preferred) to all members who have announced their intention of taking part in the Congress, within fourteen days before the meeting of the Congress, if possible.

The decisions of the Congress will be printed in all three languages and sent to all members of the Association.

SEC. 8. The Council of the Association will transact all necessary business connected with the Association.

The Council will consist of the President and the duly elected members.

Every country represented in the Association by at least twenty members has the right to propose one member as member of the Council.

The President will be elected by the Congress, the Council by the members belonging to the different countries.

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* The reduced price has been fixed at 10 Mks.= 10 shillings = $2.50, This sum may be sent in with the subscriptions. The yearly volumes begin on January 1.

Till such election has taken place the former members of the Council remain in office.

The names of proposed new members of the Council have to be communicated to the President before each Congress.

The two Vice-Presidents will be elected by the Council from among its own members.

The Council is entitled to transact business when it has been duly called together according to rule and when the President or one of the Vice-Presidents is present.

Members of the Council may be re-elected.

If a member of the Council resigns during his term of office, the President shall immediately direct the election of a substitute by the members belonging to the country in question.

In the event of the death or resignation of the President, the Council will appoint one of its members to carry on the presidential duties till the next Congress.

The term of office of the Council lasts from one Congress till the next.

Sec. 9. The business of the Association will be attended to by the President, assisted by a paid Secretary.

The members of the Council will attend to the business of the Association in the country which they represent.

Sec. 10. The resolutions of the Congresses on technical questions merely serve to express the opinion of the majority. They are therefore in the form of recommendations and are in no way binding.

Sec. 11. The resolutions of the Congresses can only be carried if at least three-fourths of the recorded votes are in favor of them. Every member of the Association present, as well as every representative of official bodies and technical societies, has one vote.

The rights and duties of a member of the Association are not altered by the fact of his belonging at the same time to a national or other Association which Association is itself a member of the International Association.

Sec. 12. The technical problems to be considered by the Association will be decided upon by the Congresses and by the Council and will be duly referred to commissions or reporters appointed by the Council.

Sec. 13. The Council draws up its own regulations according to the By-Laws of the Association and to the needs which may from time to time present themselves.

Sec. 14. In the event of the Association being dissolved, any funds belonging to it will be handed over to the "International Red Cross Association."

THE INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

Technical Problems, Committees* and Referees.

As constituted in August, 1903.

SECTION A.

METALS.

Problem 1.—On the basis of existing specifications, to seek methods and means for the introduction of international specifications for testing and inspecting iron and steel of all kinds. (Proposed at the Zurich Congress, 1895.)

Committee:

Chairman, A. Rieppel, Aeussere Cramer-Klettstrasse 12, Nuremburg, Germany.

Vice-Chairman, G. Alpherts, Koninginnegracht 66, Hague, Holland.

American Members, H. H. Campbell, James Christie, Carnegie Steel Company, represented by John McLeod; Franklin Institute, represented by Wm. H. Wahl, Paul Kreuzpointner, R. Moldenke, W. R. Webster, Walter Wood.

Problem 2.—To establish methods of inspection and testing for determining the uniformity of individual shipments of iron and steel. (Proposed at the Stockholm Congress, 1897.)

Committee:

Chairman, W. Ast, Nordbahnhof, Vienna, Austria.

Vice-Chairman (office vacant).

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*The names of only the Chairmen, the Vice-Chairmen, and American Members of International Committees are here given.

American Members, Booth, Garrett and Blair, Thos. Gray, Gus. C. Henning, Paul Kreuzpointner, A. A. Stevenson, W. R. Webster, Albert Sauveur.

Problem 4.—Methods for testing welds and weldability. (Proposed at the Zurich Congress, 1895.)
Referee, R. Krohn, Gutehoffnungshuette, Sterkrade, Germany.

Problem 5.—Collection of data for establishing standard rules for piece tests, with special reference to axles, tires, springs, pipes, etc. (Proposed at the Zurich Congress, 1895.)

Committee:

Chairman, W. Rayl, Nordbahnstrasse 50, Vienna, II, Austria.
Vice-Chairman, A. Sailler, Favoritenstrasse 20, Vienna, IV, Austria.
American Members, M. H. Wickhorst, H. V. Wille.

Problem 6.—On the most practical methods of polishing and etching for the macroscopic study of iron and steel. (Proposed at the Zurich Congress, 1895.)
Referee, E. Heyn, Carmerstrasse 15, Charlottenburg, Germany.

Problem 25.—To establish uniform methods of testing cast iron and finished castings. (Proposed at the Buda-Pesth Congress, 1901.)

Committee:

Chairman, R. Moldenke, P. O. Box 432, New York, N. Y.
American Members, Alex. E. Outerbridge, Jr., Albert Sauveur, Thos. D. West.

Problem 26.—Tests with notched bars for ascertaining the relations between the different methods of testing and for fixing the numerical values representing the different properties of metals. (Proposed at the Buda-Pesth Congress, 1901.)
Referee, Ed. Sauvage, Rue Eugène Flachat 14, Paris, France.

Problem 27.—Ball-pressure tests for ascertaining the relations between the different methods of testing and for fixing the numerical values representing the different properties of metals. (Proposed at the Buda-Pesth Congress, 1901.)

Referees, J. A. Brinell, Chief Engineer, Jernkontoret, Stockholm, Sweden; G. Dillner, Director Royal Laboratory for Testing Materials, Stockholm, Sweden.

Problem 28.—The consideration of the magnetic and electric properties of materials in connection with their mechanical testing. (Proposed at the Buda-Pesth Congress, 1901.)

Referees, K. Hochenegg, Techn. Hochschule, Karlsplatz, Vienna, IV, Austria; M. von Hoor Tempik, Kgl. techn. Hochschule, Buda-Pesth, Hungary.

SECTION B.

NATURAL AND ARTIFICIAL BUILDING STONES AND THEIR CEMENTS.

Problem 7.—On the relation of chemical composition to the weathering qualities of building stones; the influence of smoke, especially sulphurous acid on building stones; the weathering qualities of roofing slates. (Proposed at the Zurich Congress, 1895.)

Committee:

Chairman, A. Hanisch, Schellinggasse 13, Vienna, I, Austria.
Vice-Chairman, P. Larivière, Quai Jemmapes 170, Paris, France.
American Members, J. F. Kemp, Mansfield Merriman.

Problem 9.—On rapid methods for determining the strength of hydraulic cements. (Proposed at the Zurich Congress, 1895.)

Committee:

Chairman, F. Berger, Rathhaus, Vienna, I, Austria.

Vice-Chairman, L. von Tetmajer, Techn. Hochschule, Karlsplatz, Vienna, IV, Austria.
American Members, W. W. Maclay, Chas. McKenna.

Problem 10.—To digest and evaluate the resolutions of the conferences of 1884–1893 concerning the adhesive qualities of hydraulic cements.
Referee, R. Féret, Boulogne-sur-Mer, France.

Problem 11.—To establish methods for testing puzzolanas with the object of determining their value for mortars. (Proposed at the Zurich Congress, 1895.)

Committee:

Chairman, G. Herfeldt, Andernach, Germany.
Vice-Chairman, C. Segré, Ancona, Italy.
American Member, A. Lundteigen.

Problem 12.—Investigation on the behavior of cements as to time of setting and on the best method for determining the beginning and the duration of the process of setting. (Proposed at the Zurich Congress, 1895; enlarged in conformity with the resolution of the Buda-Pesth Congress, 1901.)

Committee:

Chairman, E. Candlot, rue d'Edimbourg 18, Paris, France.
Vice-Chairman, N. Lamine, Zabalkansky 9, St. Petersburg, Russia.
American Members, Spencer B. Newberry, Clifford Richardson.

Problem 13.—On the normal consistency of cement mortars for test specimens. (Proposed at the Zurich Congress, 1895.)

Committee:

Chairman, A. Greil, Rathhaus, Vienna, I, Austria.
Vice-Chairman, L. von Tetmajer, Techn. Hochschule, Karlsplatz, Vienna, IV, Austria.
American Member, R. L. Humphrey.

Problem 29.—Determination of the liter weight of cement. The strength of neat hydraulic cements. Determination of a standard sand. (Proposed at the Buda-Pesth Congress, 1901.)
Referees, N. Belelubski, Rue Serpuchowskaja 4, St. Petersburg, Russia; F. Schuele, Eidg. Polytechnikum, Zurich, Switzerland.

Problem 30.—Determination of the simplest method for the separation of the finest particles in Portland cement by liquid and air processes. (Proposed at the Buda-Pesth Congress, 1901.)
Referee, M. Gary, Kgl. mech.-techn. Versuchsanstalt, Charlottenburg, Germany.

Problem 31.—On the behavior of cements in sea water. (Proposed at the Buda-Pesth Congress, 1901.)
Referee, H. Le Chatelier, Place du College de France 9, Paris, France.

Problem 32.—On accelerated tests of the constancy of volume of cements. (Proposed at the Zurich Congress, 1895.)

Committee:

Chairman, Bertram Blount, Broadway, Westminster, London, S. W., England.
Vice-Chairman (office vacant).
American Members, R. W. Lesley, Spencer B. Newberry.

Problem 33.—On the influence of the proportion of water and sand on the strength of Roman and other cements. (Proposed at the Buda-Pesth Congress, 1901.)
Referee, The Hungarian Society for Testing Materials, Buda-Pesth, Hungary.

SECTION C.

OTHER MATERIALS.

Problem 17.—On methods of testing tile pipes. (Proposed at the Stockholm Congress, 1897.)
Referee, M. Gary, Kgl. mech.-techn. Versuchsanstalt, Charlottenburg, Germany.

Problem 18.—On the methods of testing the protective power of paints used on metallic structures. (Proposed at the Zurich Congress, 1895.)
Referees, Albert Grittner, Kobanyai ut 30, Buda-Pesth, Hungary; E. Ebert, Centralbahnhof, Munich, Germany.

Problem 19.—On uniform methods for testing lubricants. (Proposed at the Zurich Congress, 1895.)
Referee, N. Petroff, Zagorodny 70, St. Petersburg, Russia.

Problem 23.—On uniform methods for compression tests of wood.

Committee:

Chairman, Prof. A. Schwappach, Eberswalde, Germany.
Vice-Chairman, A. Wykander, Goeteborg, Sweden.
American Member, Filibert Roth.

Problem 35.—Study of the methods of testing caoutchouc. (Proposed at the Buda-Pesth Congress, 1901.)

Committee:

Chairman, E. Camerman, Rue Philippe Le Bon 73, Brussels, Belgium.
Vice-Chairman (office vacant).
American Member, R. G. Pearson.

SECTION D.

MISCELLANEOUS SUBJECTS.

Problem 22.—Considering that the resolutions formed by the International Conferences of Munich, Dresden, Berlin, Vienna and Zurich, for the purpose of attaining unity in the methods of testing materials, and the report of the Committee of the American Society of Mechanical Engineers do not agree in many points with the decisions arrived at by the French commission, it is proposed that the Council appoint a commission which shall prepare a report upon these differences, and proposals for ways and means of abolishing them.

Committee:

Chairman, N. Belelubski, Rue Serpouchowskaya 4, St. Petersburg, Russia.

Vice-Chairmen, A. Martens, Kgl. mech.-techn. Versuchsanstalt, Charlottenburg, Germany; E. Sauvage, l'Ecole des Mines, Paris, France.

American Members, Albert Ladd Colby, Gus. C. Henning, R. Moldenke, George F. Swain, George S. Webster, W. R. Webster, Walter Wood.

Problem 24.—On uniform nomenclature of iron and steel. (Resolution of Council, February 3, 1901.)

Committee:

Chairman, H. M. Howe, 27 West Seventy-third street, New York, N. Y.

Vice-Chairmen, L. Lévy, Rue de La Rochefoucauld 19, Paris, France; D. Tschernoff, Rue Pessatschenaia 25, St. Petersburg, Russia.

Secretary, Albert Sauveur, 446 Tremont street, Boston, Mass.

American Member, H. H. Campbell.

Problem 34.—Fixing a uniform definition and nomenclature of the bitumens. (Proposed at the Buda-Pesth Congress, 1901.)

Committee:

Chairman, G. Lunge, Eidg. Polytechnikum, Zurich, Switzerland.
Vice-Chairman, Jenoe Kovacs, Tataros (Post Mezoe Telegd), Hungary.
American Members, A. W. Dow, Clifford Richardson.

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